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RESEARCH DIRECTED TOWARD THE USE OF SYNOPTIC SIMULATION TO DEVELOP FORECAST MODELS COMPATIBLE FOR USE IN SYSTEM 433L

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EASTERN AIR LINES, INC.
Meteorology Department
Atlanta, Georgia

PROJECT 8641
TASK 86411

FINAL REPORT

Contract No. AF19 (604)-7374
June 14, 1962

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ABSTRACT

Methods for forecasting visibility at 1200Z from observations at 0600Z and earlier for Idlewild and Washington National Airports are given. The methods include a subjective classification of the 0600Z sea-level chart with respect to the station. The synoptic pressure patterns include Post-trough, Pre-trough, Pre-warm Front, Smoke Patterns, In High, In Low, Hurricanes and Changing Patterns. Solutions for Post-trough and Smoke Patterns involve an automatic forecast. Solutions for the Pre-trough pattern are divided into cases with maritime history and those with continental history. The same basic parameters are used at both stations, an additional predictor being required at Idlewild. The solutions are stratified by months. The Pre-warm Front system applies only to Idlewild. Two solutions are given, one using a seasonal stratification, the other a general solution applicable in any season. All predictors are objective and computations simple.

The combined solution forecast visibility correctly in 2407 out of 2633 cases.

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RESEARCH DIRECTED TOWARD THE USE OF SYNOPTIC SIMULATION TO DEVELOP FORECAST MODELS COMPATIBLE FOR USE IN SYSTEM 433L

INTRODUCTION

The purpose of this research is to put synoptic forecasting models into objective language adaptable to computer methods. The particular problem is forecasting visibility for a six-hour period.

The ultimate purpose is the extension of a synoptic forecast system to universal application both time-wise and geographically. It is expected that a final solution will consist of several sections, the first identifying the state of the air with respect to moisture and stability and the second containing elements reflecting local effects such as smoke pollution or topographic effects. That is, as the solution is transferred geographically, one section will remain universally applicable but will be modified by a second section which contains local factors. The tentative solutions described later follow this thesis to some extent. No attempt has been made to make the solution universally applicable from the standpoint of time. All material refers to a forecast starting time of 0600Z and a verifying time of 1200Z.

The success of a synoptic approach depends upon the skill with which the meteorologist is able to catalogue certain basic pressure patterns which highlight the particular visibility problem he faces. The synoptic approach to be described recognizes five basic pressure patterns, of a very general nature, as the foundation of the synoptic simulation system. No attempt has been made to apply an objective measure to this classification.

A number of authors, George (1), Buma (2), among others, have emphasized the influence of visibility restrictions in air with a water history as opposed to continental type air masses. It seemed advisable that the dependent sample include stations which experience various possible types of air mass trajectory. For this reason, Idlewild and

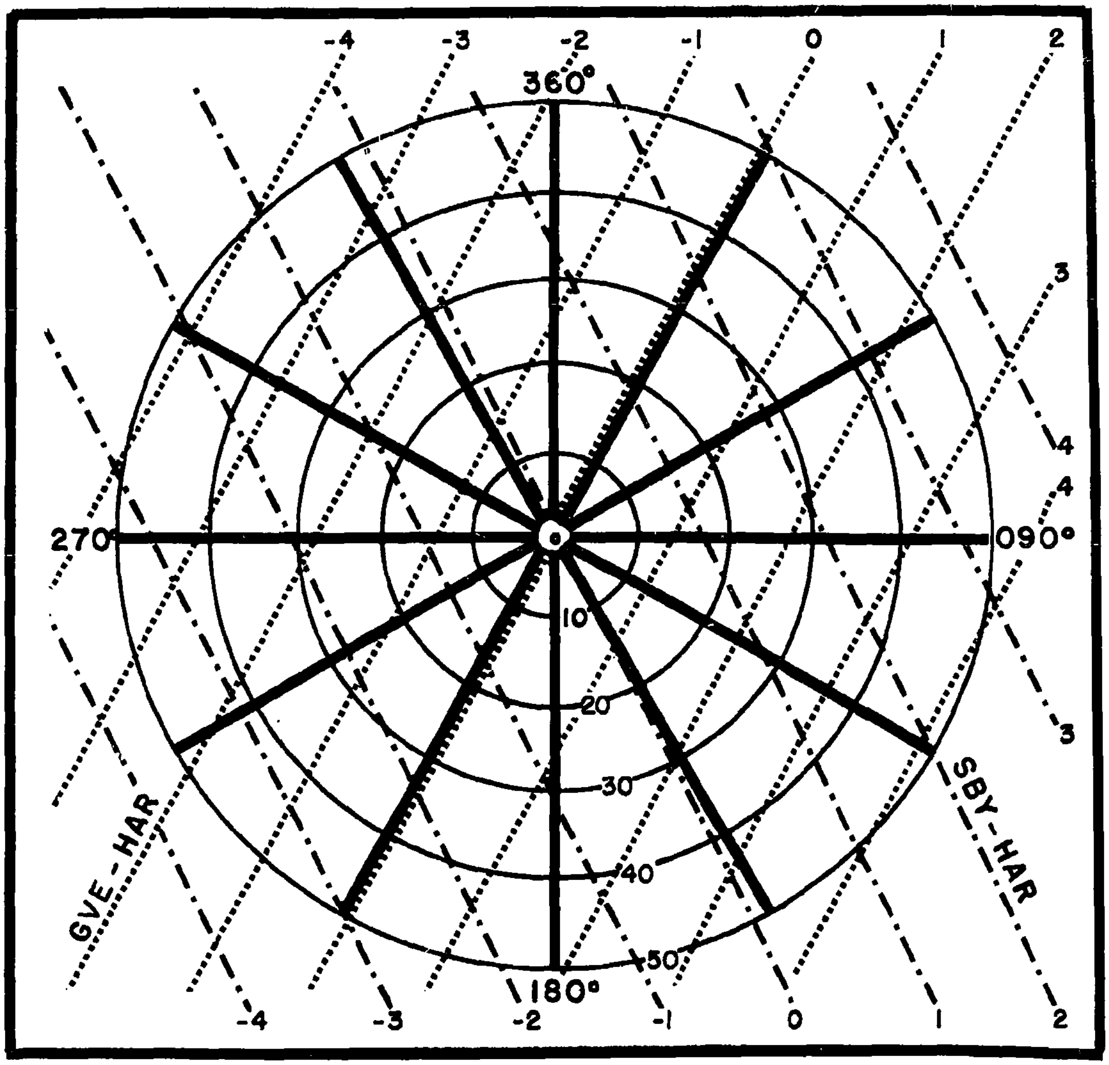
Washington National airports have been studied. Idlewild was chosen for its proximity to water and industrial pollution sources. Washington on the other hand, experiences little smoke pollution and has a smaller percentage of cases with water history. Reference is made to the trajectory of the air as being either "water" or "land." These are arbitrary definitions dictated by the data and refer to certain geostrophic wind directions.

The data have been tabulated by months and in general, all solutions are stratified by months. In some cases a number of months have been grouped and a seasonal stratification is defined. Two solutions are given for "Pre-warm Front" visibilities: the first is seasonal and the second groups all months into one solution.

The dependent data sample consists of 60 months of data at Idlewild and 60 months at Washington National. For the months of January through May, the years 1956 through 1960 were used and for April through December the years 1955 through 1959 were used. Selected data for test purposes were drawn from the years 1952, 1953, 1954, and 1955. All observations prior to July 1957 were collected on the half-hour, therefore, the solutions contain some cases using a time period of 0630Z to 1230Z and those after June 1957 with a time period 0600Z to 1200Z. Due to a lack of data, precipitation information was taken from the records of LaGuardia Airport instead of Idlewild. Similarly, use is made of normal monthly average temperatures at Idlewild and these too were made from the LaGuardia records.

Use is made of the geostrophic wind. The objective method described by Hovde and Reber (3) is used as a means of obtaining this parameter. The method employs the sea level pressures of a triangle of stations surrounding the station in question to arrive at the geostrophic wind. The stations used for Idlewild were Providence, Rhode Island, Wilkes Barre, Pennsylvania, and Atlantic City, New Jersey. The stations used in the computation at Washington were Harrisburg, Pennsylvania, Salisbury, Maryland, and Gordonsville, Virginia. The observations from the latter station have since been discontinued and are now being taken at Charlottesville, Virginia. Any independent test extending into 1961 will require a new geostrophic graph. The graphs for determining geostrophic wind are given in figs. 1 and 2.

WASHINGTON GEOSTROPHIC WIND



GVE-HAR

SBY-HAR

Fig. 1. Use sea level pressure in units and tenths of millibars. To obtain the geostrophic wind, plot the GVE pressure minus the HAR pressure versus the SBY pressure minus the HAR pressure. This plot gives the geostrophic velocity in knots, as read off of the 10 knot circles, and the reciprocal of the geostrophic direction.

IDLEWILD GEOSTROPHIC WIND

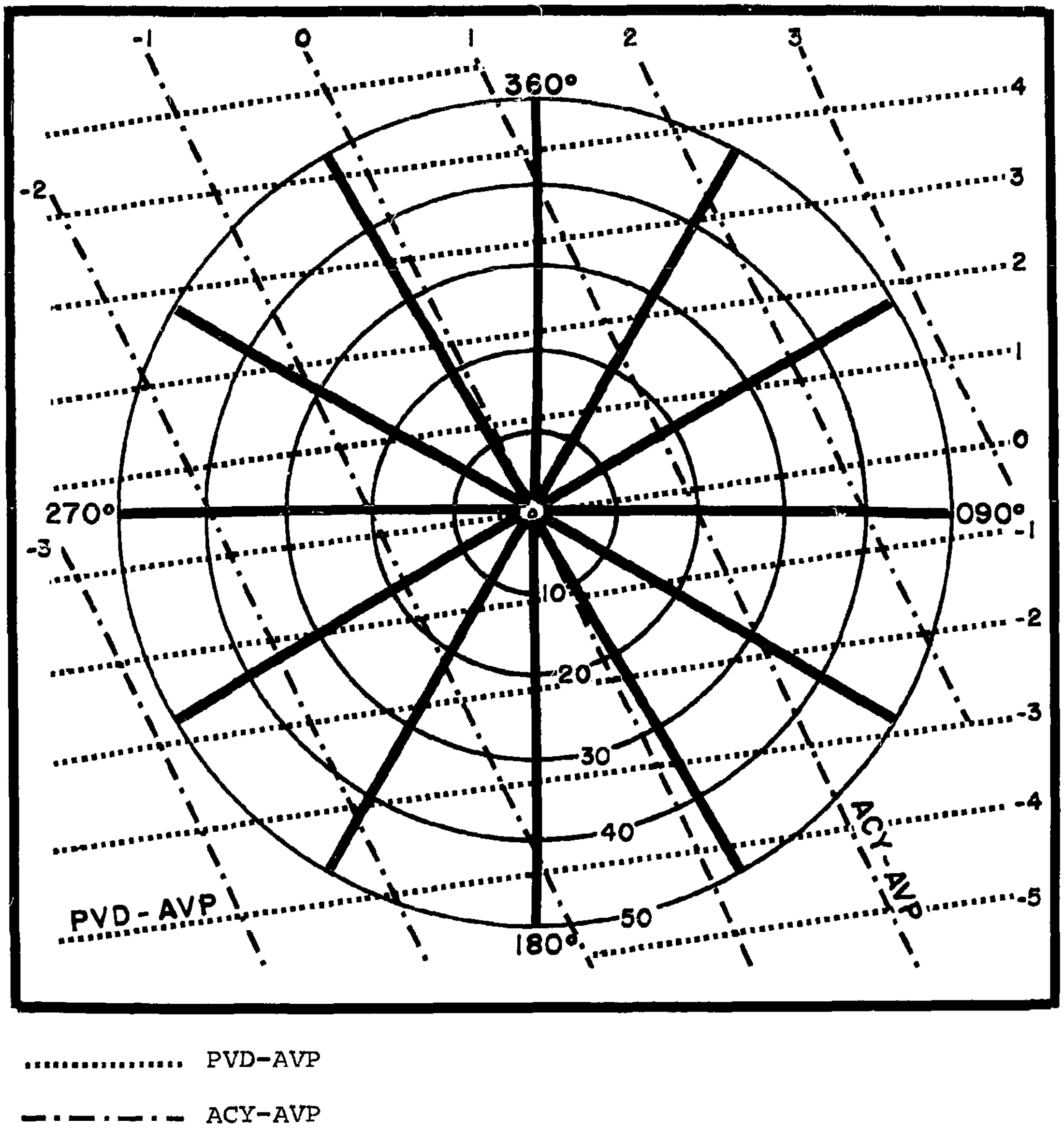


Fig. 2. Use sea level pressure in units and tenths of millibars. To obtain geostrophic wind, plot the PVD pressure minus the AVP pressure versus the ACY pressure minus the AVP pressure. This plot gives the geostrophic velocity in knots, as read off of the 10 knot circles, and the reciprocal of the geostrophic direction.

Visibility values have been stratified into three categories as follows:

Category I : less than 1 mile.
Category II : 1 through 3 miles.
Category III: greater than 3 miles.

These values have been simplified on some graphs to the Roman numerals I, II, and III.

The first step in the synoptic method is classification of the sea-level pressure chart with respect to the station in question, in this case either Idlewild or Washington. These classifications refer to the appearance of the map at 0600Z. It is assumed that the 0600Z classification will not change by 1200Z. Any cases which did show a change of pattern in the six-hour period were automatically placed in the "changing pattern" classification list, and no solution has been attempted.

The classifications which follow are subjective at this time and represent what a meteorologist at Idlewild or Washington would see on the sea-level map with respect to his station:

<u>Post-trough, Post-cold Front, Post-Low, Pre-High</u>

The unmistakable example of this pattern is the case when a cold front or a low has just moved east of the station. In essence, it implies that fresh air is being transported to the station. In general, it is applied when an eastward moving or stationary high or ridge line is oriented west of the station.

<u>Pre-trough, Pre-cold Front, Post-High</u>

This pattern is characterized by an approaching cold front or trough and implies that modified or warmer air is being transported into the station. Generally, anticyclones or ridge lines are oriented east of the station.

<u>Pre-low, Pre-warm Front</u>

This pattern is generally regarded as the "weather producer." The station will lie on the cold air side of the warm front throughout the period. In the case of an approaching low, the station will generally be located in a manner such that the cyclone will pass over or to the south or east.

In High, In Col

This is characterized by flat gradients which result when the station is within the innermost closed isobars of an anticyclone or located in a col.

In Low

This is a rare pattern in which the station is located within the innermost closed isobar of a low.

Changing Pattern

This type is any case in which the pattern at 0600Z changes to a different pattern by 1200Z.

Special Patterns

Special patterns apply to those features or types which are regarded as unique or unusual:

HURRICANE PATTERN is characterized by a station located within the periphery of a tropical cyclone.

SMOKE PATTERN is applicable to Idlewild only and has been used only during the summer months. Its principal features include a flat ridge over the Appalachian Mountains extending northward into New York and Pennsylvania, and a slight trough near the coast from New England to Virginia or North Carolina. It is characterized by surface winds from the west-southwest to southwest at less than 15 knots. The position and orientation of these features are not especially critical as long as a drift from the west or southwest is maintained. The pressure gradient must be relatively weak, particularly through the trough, with a pressure difference of no more than about 4-6 mbs in 300 miles along the trough. See fig. 3.

The center of high pressure or ridge may range from the Ohio Valley to the southeastern or Gulf States, provided a flat ridge extends at least into Pennsylvania. The trough may be oriented from north-south to northeast-southwest and be located in the area between Vermont-eastern Pennsylvania and the Massachusetts-Virginia coast.

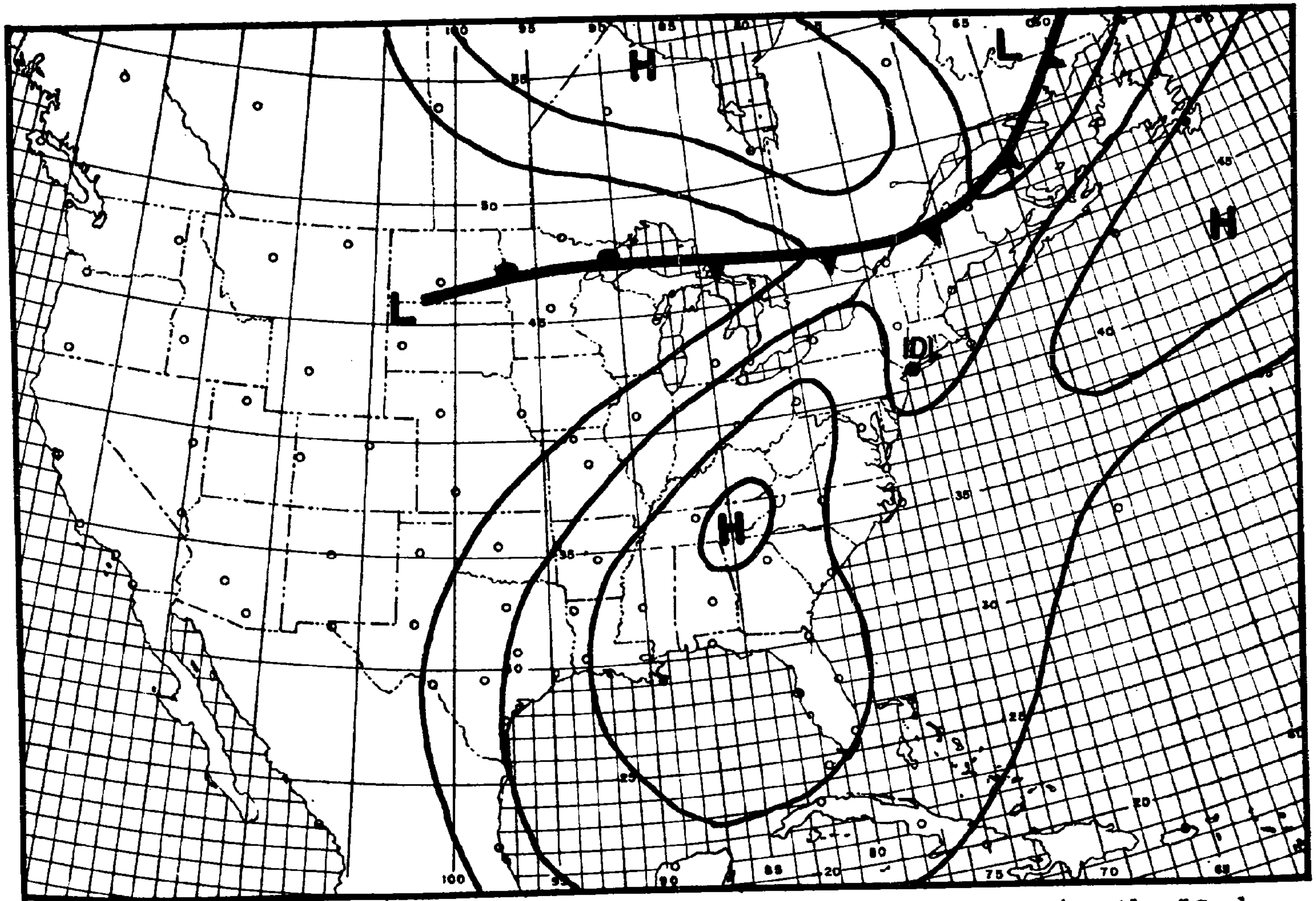


Fig. 3. Surface synoptic chart for 0600Z, 28 August 1959, illustrating the "Smoke Pattern" for Idlewild Airport. Note flat ridge extending into Pennsylvania and New York and the weak trough New England-middle Atlantic coast. The cold front through the St. Lawrence Valley or northern New England to the eastern Great Lakes may or may not be present.

SOLUTIONS

The selection of a synoptic pressure pattern is the first step to solution. As might be anticipated, each pattern stratification follows a different course to solution. No research has been attempted on the following types: In High, In Low, Changing Pattern, and Hurricanes. Solution for Post-Low, Smoke Pattern, Pre-trough and Pre-warm Front follow.

POST-LOW, POST-COLD FRONT, PRE-HIGH

As mentioned earlier this type almost implies by definition that fresh air is being transported into the station. When this pattern is observed at 0600Z, an automatic forecast of visibility greater than 3 miles is made for the station.

The results tested on 60 months' data at Washington showed that 700 cases out of 743 responded correctly. Five of the misses were due to post-frontal snow. Most of the remaining cases were caused by deceleration behind the front. Only two cases were less than one mile, apparently radiation fog in light northwest flow.

The results at Idlewild show that 682 cases out of 728 were forecast correctly. Eight of the misses were due to post-frontal snow. Thirteen errors were due to smoke which is at a maximum from these quadrants.

The combined results at the two stations show 1382 cases out of 1471 were forecast correctly, with the majority of errors in the 1-3 mile range.

It is expected that most other stations will show similar results except where local differences may indicate additional appendages are needed. An example of such a station would be Cleveland, Ohio, where this type of situation frequently brings about a lowering of visibilities due to the proximity of the lake to the north. Topography might also alter this in some cases, especially on the western slopes of mountains where upslope effects enter in.

SMOKE PATTERNS

When the smoke pattern is detected, a forecast of Category II, 1-3 miles should be made. This is a local pattern applicable only to Idlewild, and has been tested only in the summer months.

In the months June through August 1955-1959, there were a total of 74 cases in which the smoke pattern occurred. In 71 of the 74 cases visibilities were less than 7 miles. In 59 cases visibilities were 1-3 miles with one case of 3/4 mile.

PRE-TROUGH

Introduction

The pre-trough synoptic pattern as defined earlier implies the transport of warmer or modified air into a station with the lack of warm front activity. The solution presented is similar for both Washington and Idlewild in that the same predictors are used in combination. Identical processes and predictors are set up for solution, although the weight of the predictor or predictor combinations vary.

Trajectory of the air is defined by the 0600Z geostrophic wind direction as determined by the three station pressure configuration defined in the Introduction. The land or continental trajectory is defined as having a geostrophic wind between 240 and 50 degrees, (through north). The remaining sector, between 230 and 60 degrees, through south, is defined as maritime or water trajectory. The same directional limits are used at both stations.

Use is also made of normal temperatures at each station. These were obtained from the Local Climatological Data, published by the Weather Bureau. LaGuardia temperature data is used for the New York area due to the lack of such figures for Idlewild. These are given in Table I.

TABLE I

NORMAL MONTHLY AVERAGE TEMPERATURES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DCA	36	37	45	54	65	73	77	75	70	58	48	38
LGA	33	33	40	50	61	71	76	74	68	58	47	36

Method

The variables include:

1. Geostrophic wind. Direction and speed for 0600Z determined from either fig. 1 or 2.
2. Dewpoint depression. The 0600Z temperature-dewpoint difference.
3. Visibility. The 0600Z visibility in miles with fractional parts in halves, quarters, eithths or sixteenths.
4. Dewpoint. The 0600Z dewpoint.

The predictors are all combined graphically to arrive at a solution. For economy of space, a number of months have been combined on some of the figures.

With an 0600Z geostrophic wind between 240° through north to 50°, the trajectory is classed as continental. The predictors are 0600Z dewpoint depression and the geostrophic wind speed. The solution for Washington is given in figs. 4 and 5.

For cases of maritime trajectory, geostrophic winds 60° through south to 230°, the solution requires a multiple correlation. The first relationship, (Stage I), uses the geostrophic wind speed as the ordinate and the 0600Z dewpoint minus the normal monthly average temperature (Table I) as the abscissa. Weight lines on the graph determine a value which is entered on the Stage II graph. The 0600Z visibility is also entered on the seasonal stage and forecast visibility categories are read from the graph.

The maritime solutions for Washington are given in figs. 6 through 15.

At Idlewild, the continental sector is also the source of maximum smoke restriction, therefore, the 0600Z visibility is needed to refine the solution. Forecasting graphs are given in figs. 16, 17, and 18.

Idlewild maritime air solutions are given in figs. 19 through 28.

Results

The results for all seasons are given below by station.

WASHINGTON:

Continental

Observed \ Forecast	I	II	III
I	3	0	0
II	0	17	10
III	1	7	226

246/264 = 93%

Maritime

Observed \ Forecast	I	II	III
I	1	1	0
II	0	34	8
III	0	8	137

172/189 = 90%

Overall Percentage 418/453 = 92%

Skill score-random = .717
Skill score-persistence = .597

IDLEWILD:

Continental

Observed \ Forecast	I	II	III
I	10	2	1
II	0	34	14
III	0	9	135

170/196 = 87%

Maritime

Observed \ Forecast	I	II	III
I	12	0	1
II	0	35	8
III	1	12	105

152/174 = 87%

Overall Percentage 322/370 = 87%

Skill score-random = .70
Skill score-persistence = .633

WASHINGTON, PRE-TROUGH CONTINENTAL GRAPH

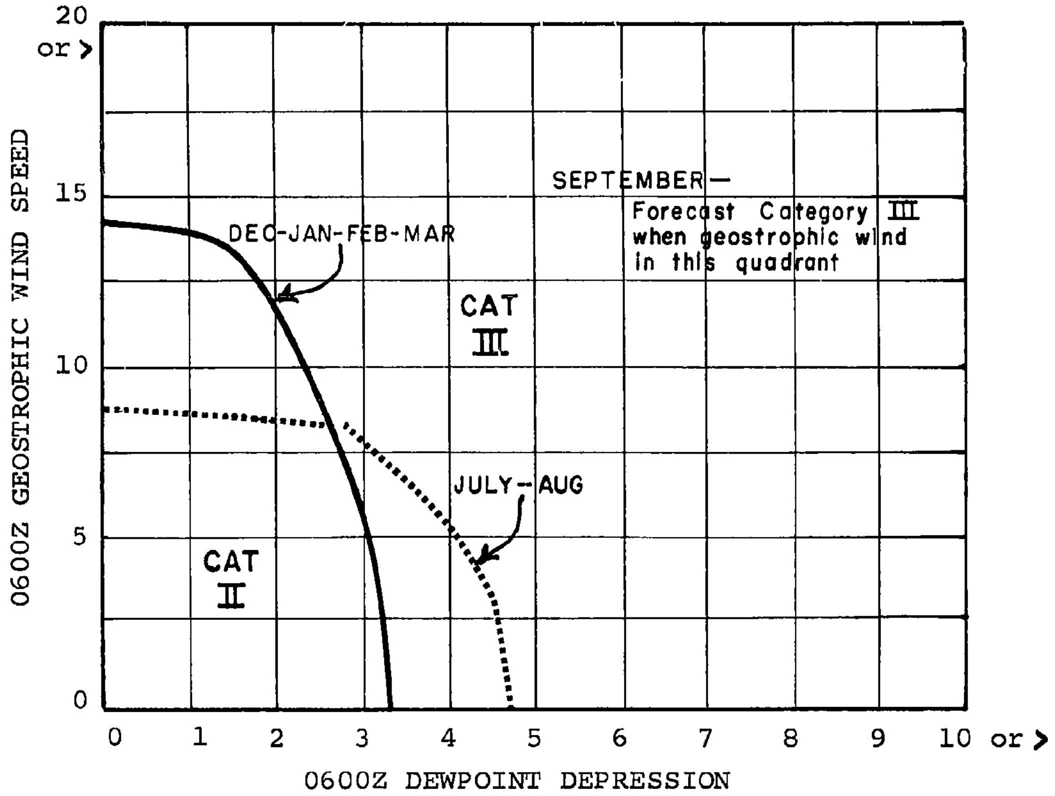


Fig. 4. For use in the months of December, January, February, March, July, August, September. With the 0600Z dewpoint depression and the 0600Z geostrophic wind speed, enter the graph and read directly the category for the forecast visibility at 1200Z. Category II values are used to the left of the lines and Category III values to the right of the lines for the respective months.

WASHINGTON, PRE-TROUGH CONTINENTAL GRAPH

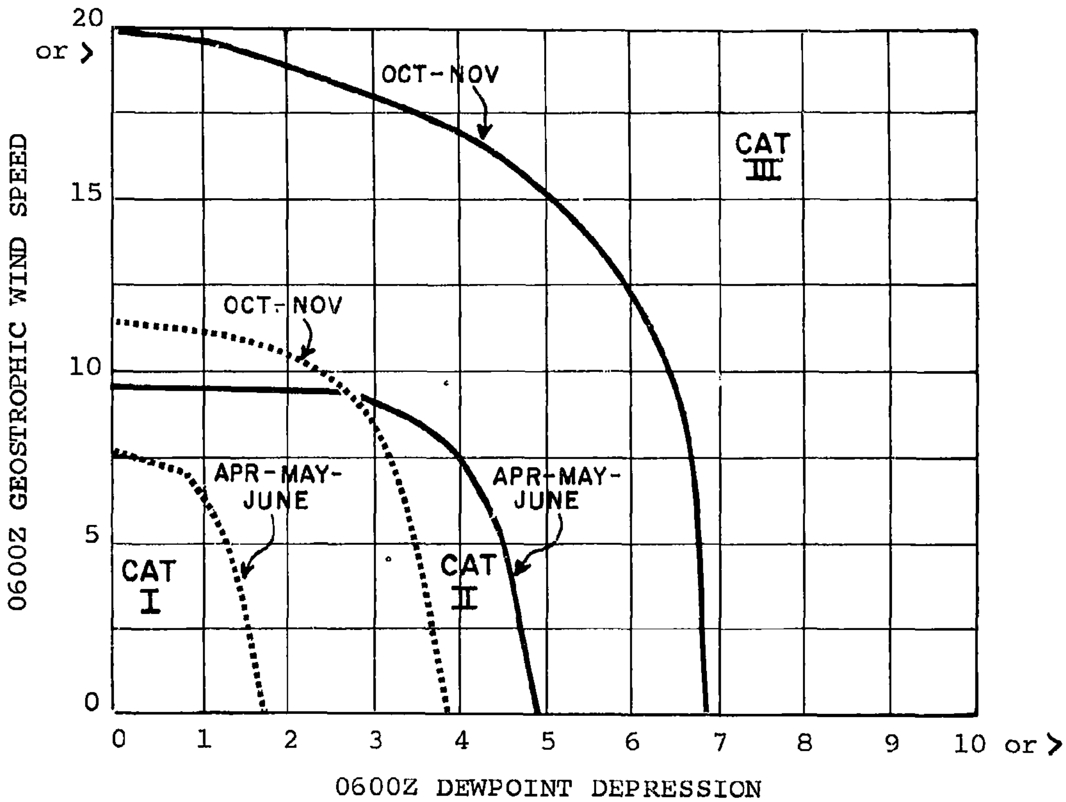


Fig. 5. For use in the months of April, May, June, October and November. With the 0600Z dewpoint depression and the 0600Z geostrophic wind speed, enter the graph and read directly the category for the forecast visibility at 1200Z. Category I values are used to the left of the dashed lines and Category II values to the left of the solid lines but to the right of the dashed curves for the respective months. Category III values are used to the right of the solid curves.

WASHINGTON, PRE-TROUGH MARITIME, STAGE I

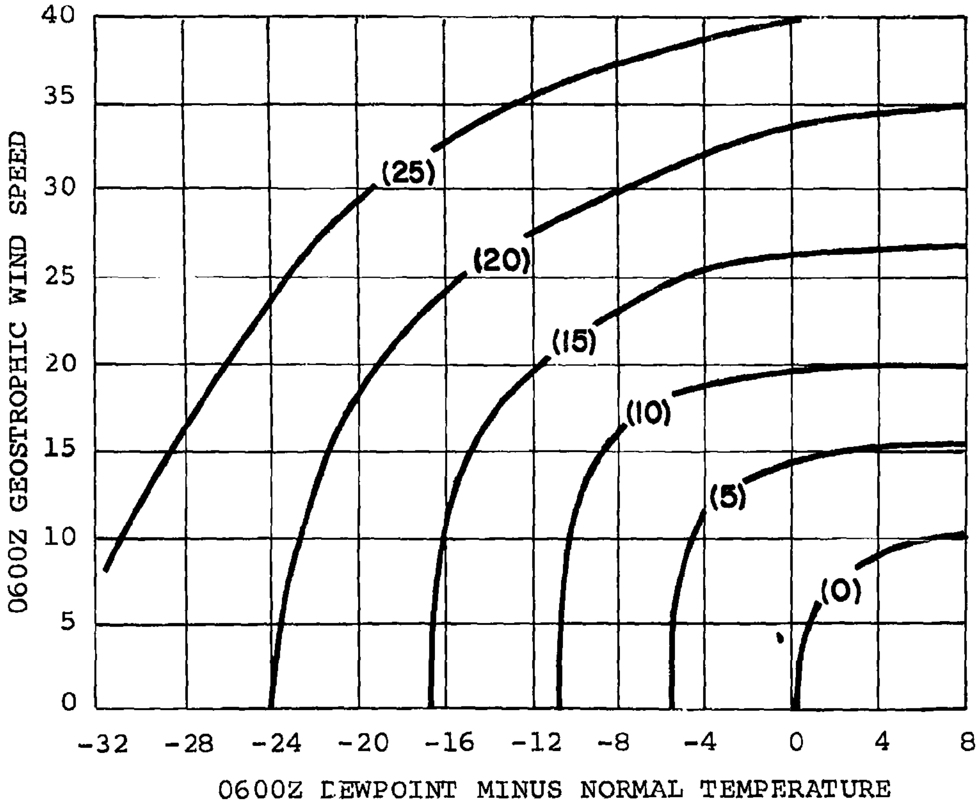


Fig. 6. For use in the months of December, January, February and March. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 7).

WASHINGTON, PRE-TROUGH MARITIME, STAGE II

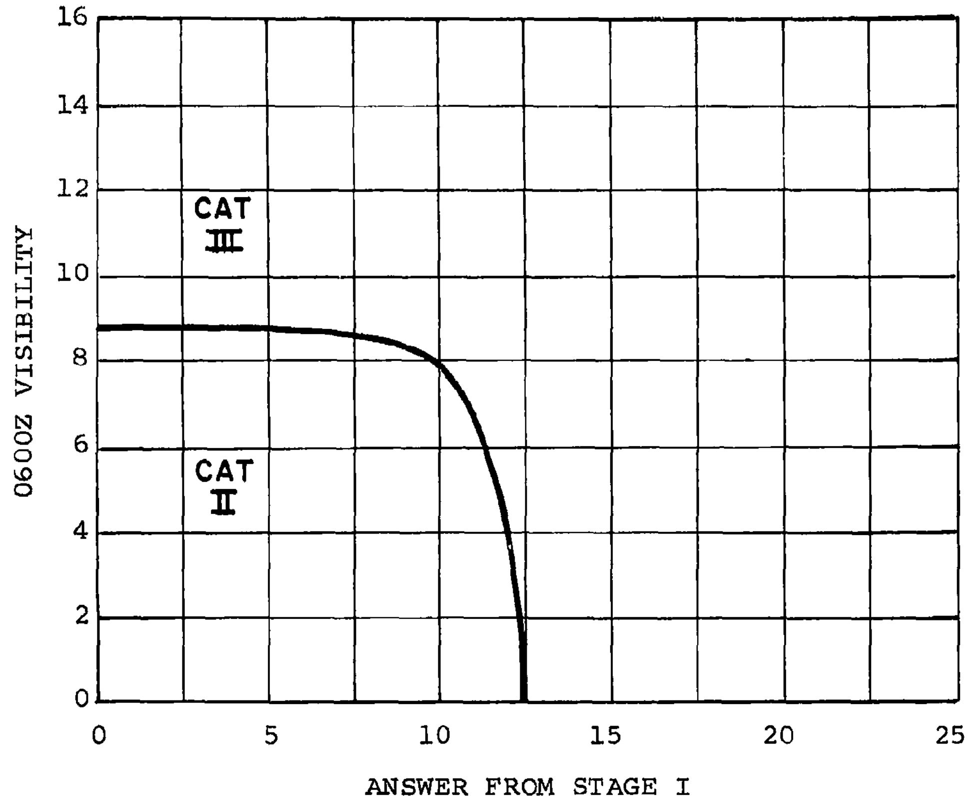


Fig. 7. For use in the months of December, January, February and March. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

WASHINGTON, PRE-TROUGH MARITIME, STAGE I

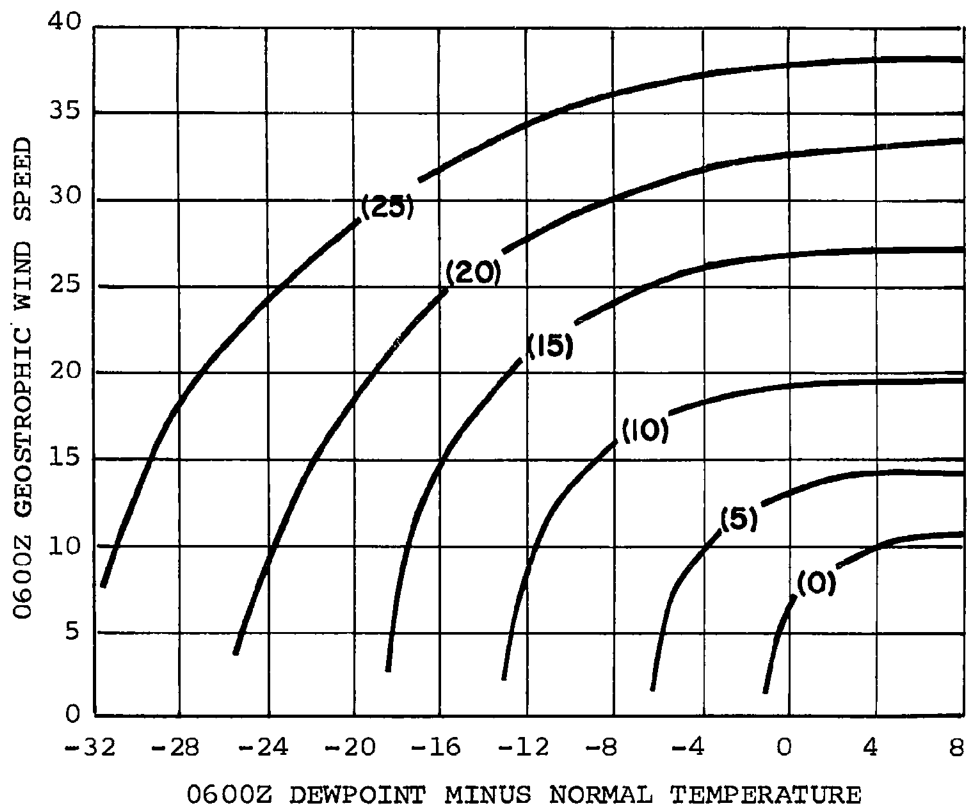


Fig. 8. For use in the months of April, May and June. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 9).

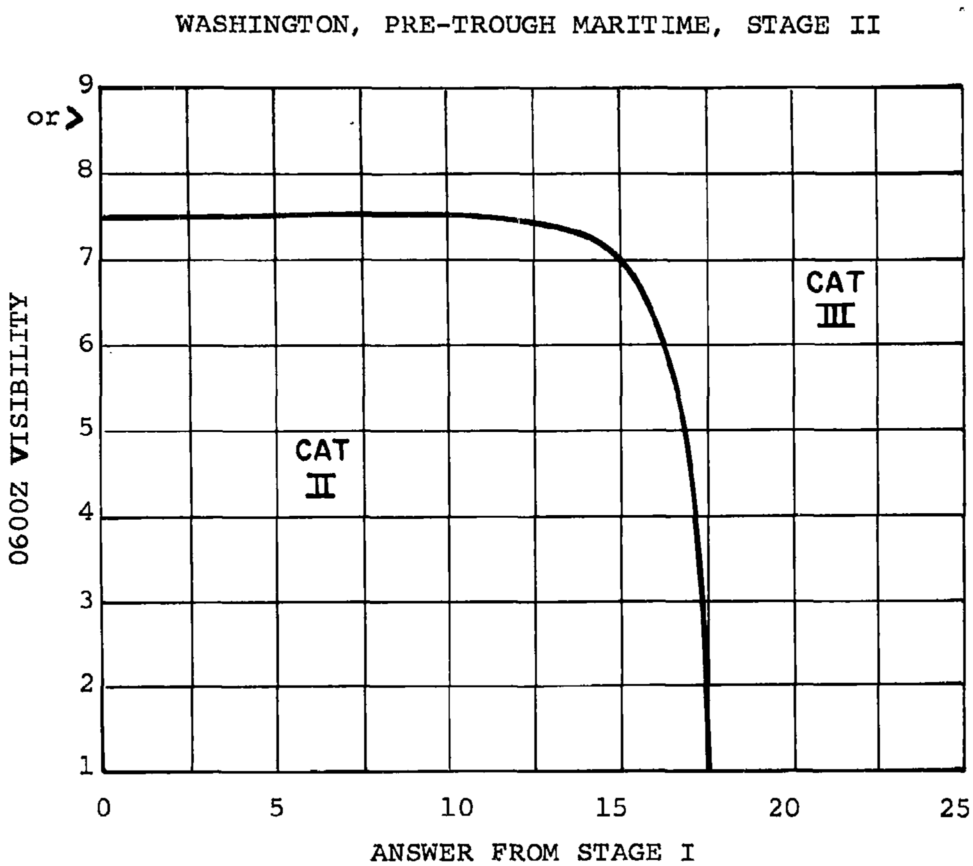


Fig. 9. For use in the months of April, May and June. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

WASHINGTON, PRE-TROUGH MARITIME, STAGE I

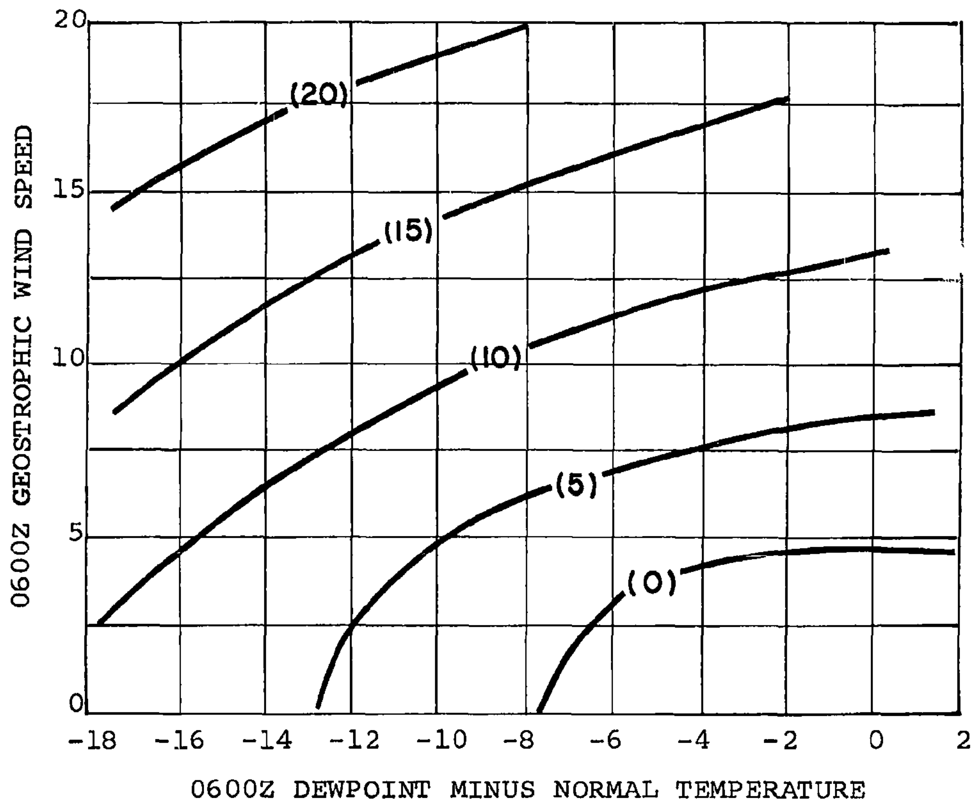


Fig. 10. For use in the months of July and August. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 11).

WASHINGTON, PRE-TROUGH MARITIME, STAGE II

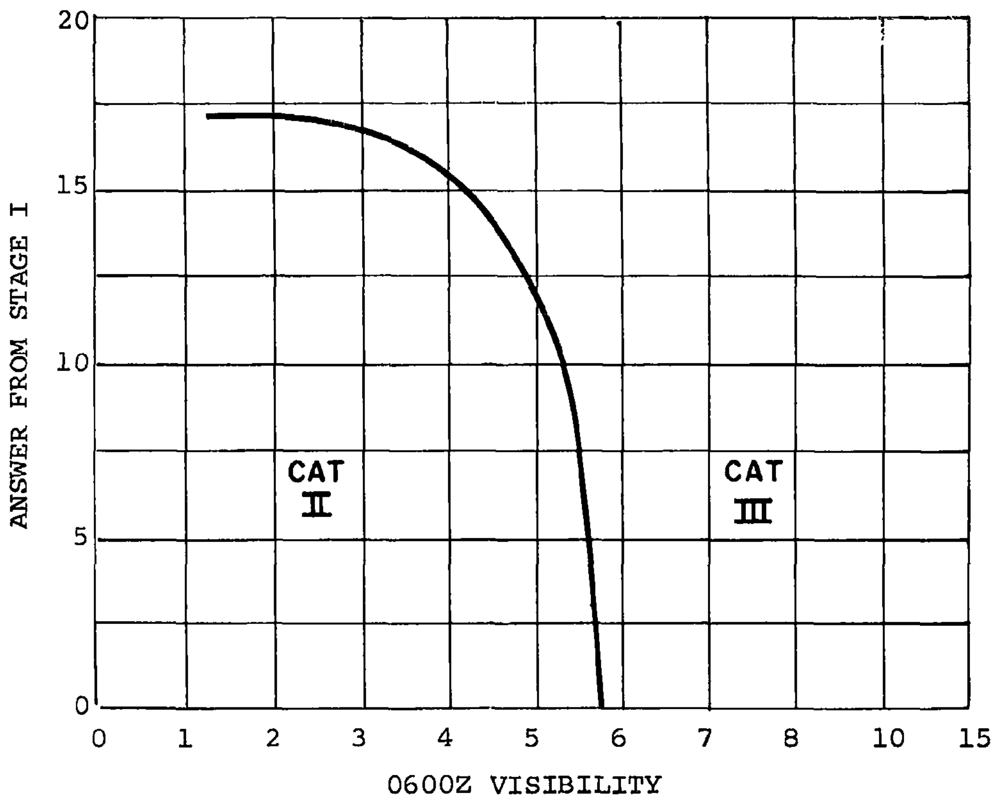


Fig. 11. For use in the months of July and August. With the answer from Stage II and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

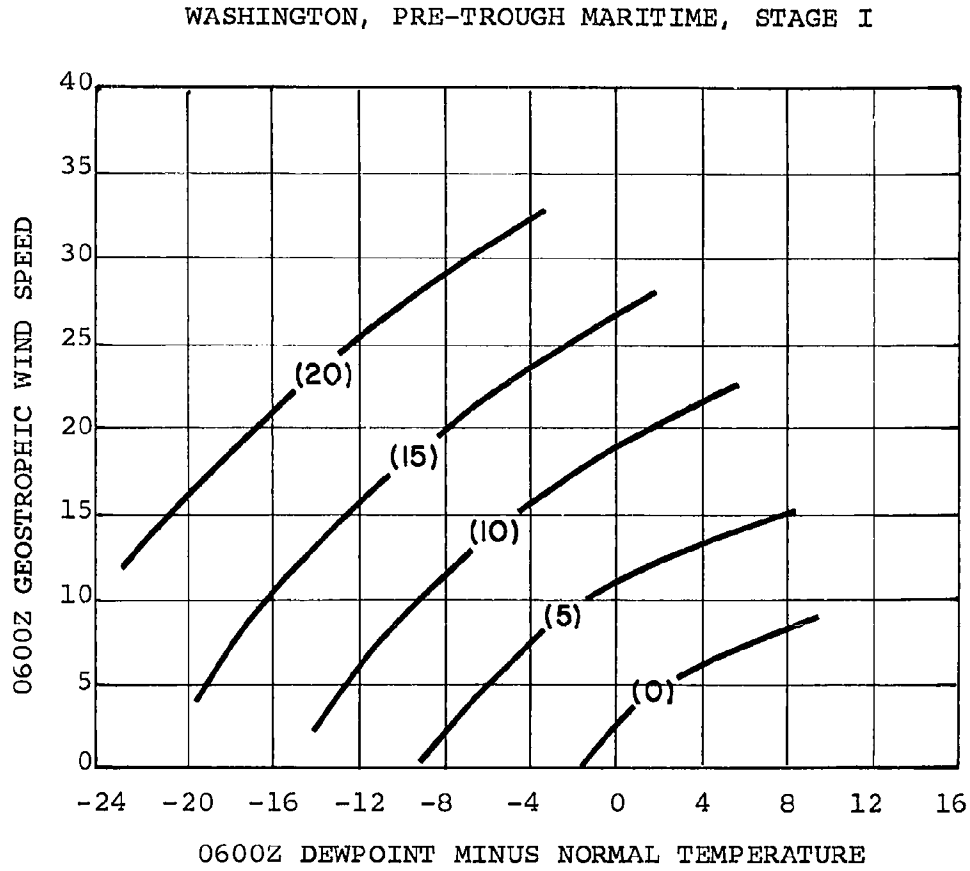


Fig. 12. For use in the month of September. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 13).

WASHINGTON, PRE-TROUGH MARITIME, STAGE II

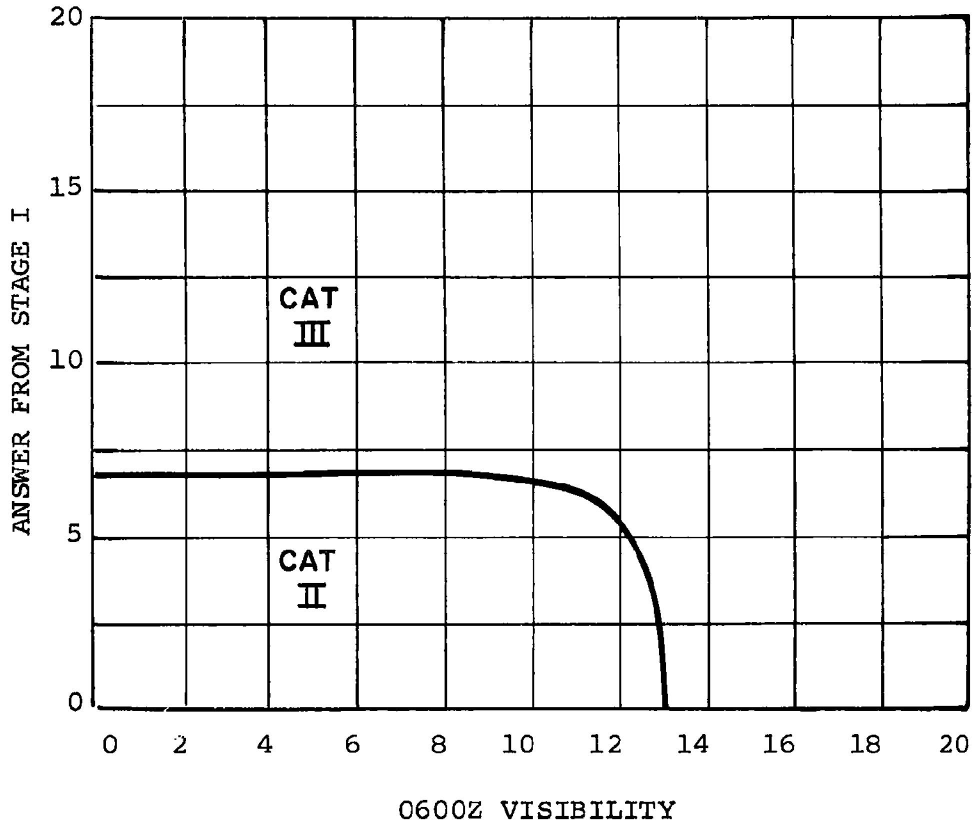


Fig. 13. For use in the month of September. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

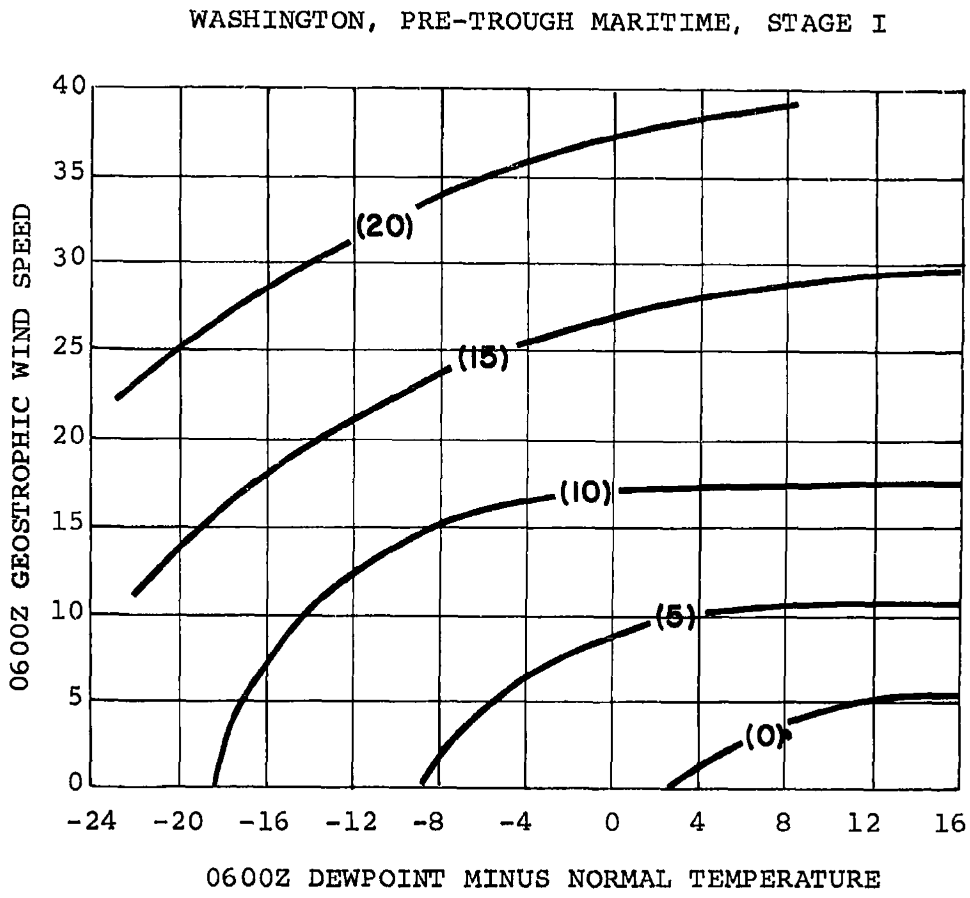


Fig. 14. For use in the months of October and November. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 15).

WASHINGTON, PRE-TROUGH MARITIME, STAGE II

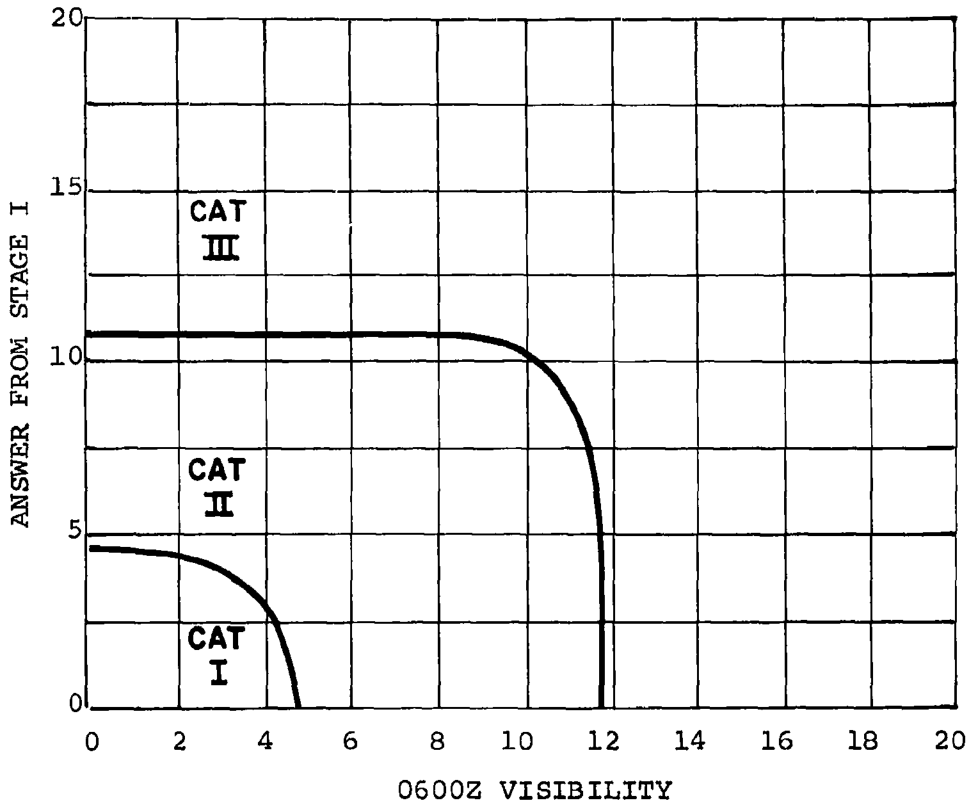


Fig. 15. For use in the months of October and November. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

IDLEWILD, PRE-TROUGH CONTINENTAL GRAPH

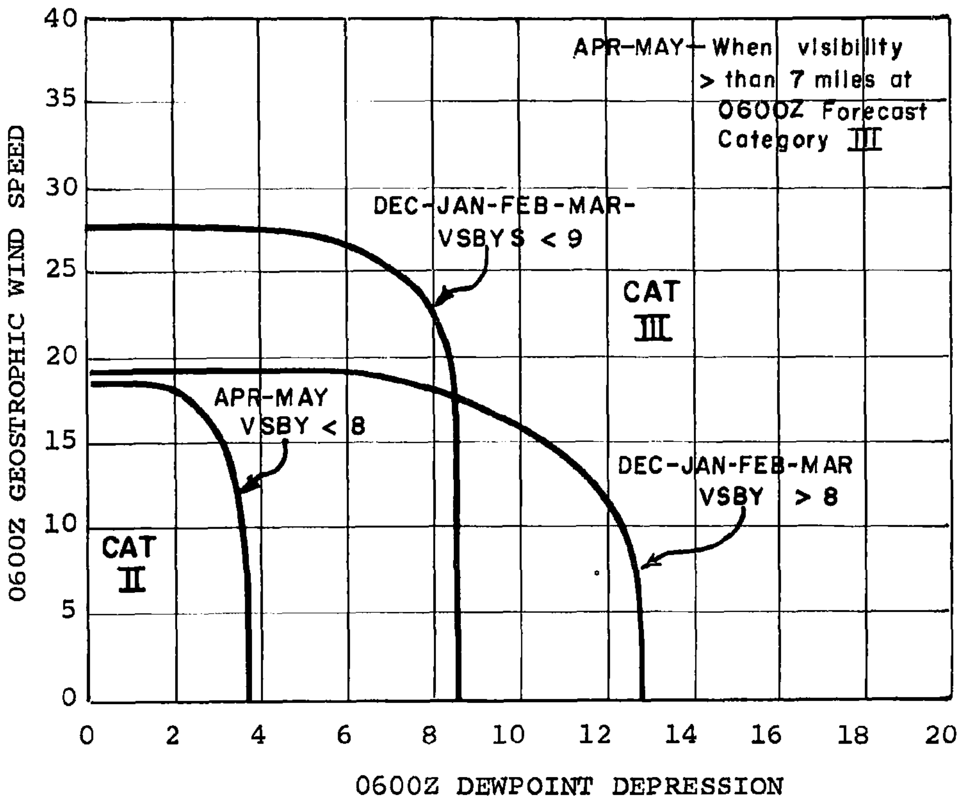


Fig. 16. For use in the months of December, January, February, March, April and May. With the 0600Z dewpoint depression and the 0600Z geostrophic wind speed, enter the graph and read directly the category for the forecast visibility at 1200Z. Category II values are used to the left of the lines and Category III values to the right of the lines for the respective months.

IDLEWILD, PRE-TROUGH CONTINENTAL GRAPH

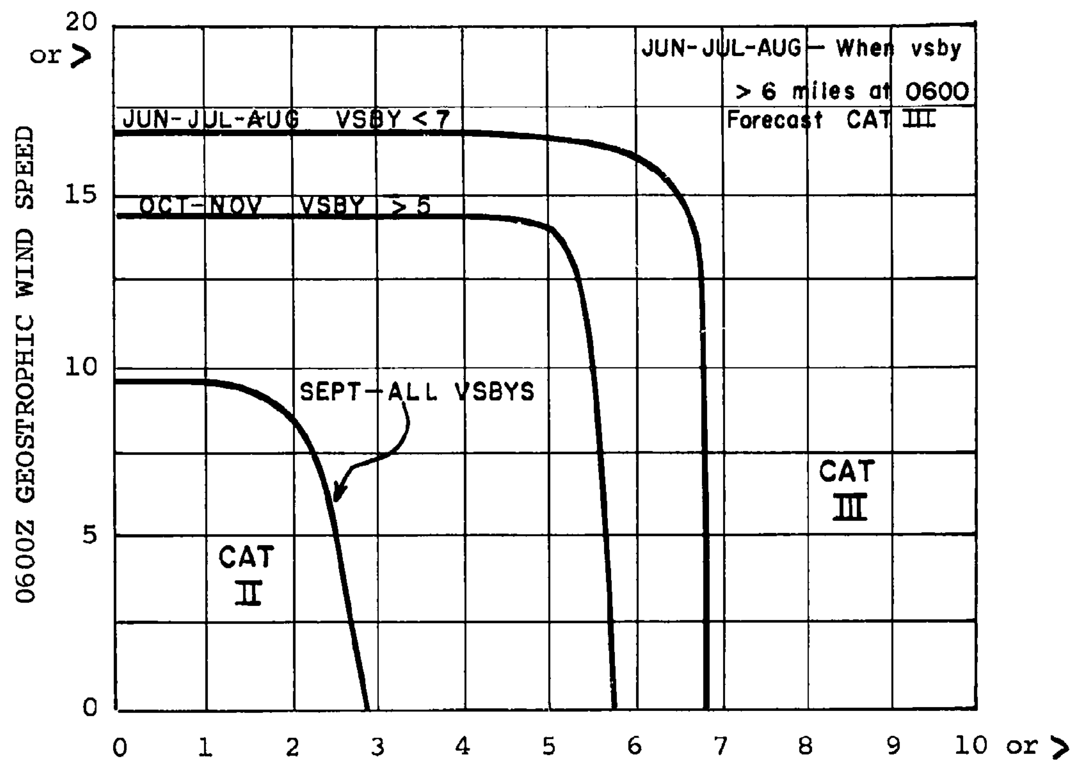


Fig. 17. For use in the months of June, July, August, September, October and November. With the 0600Z dew-point depression and the 0600Z geostrophic wind speed, enter the graph and read directly the category for the forecast visibility at 1200Z. Category II values are used to the left of the lines and Category III values to the right of the lines for the respective months.

IDLEWILD PRE-TROUGH CONTINENTAL GRAPH

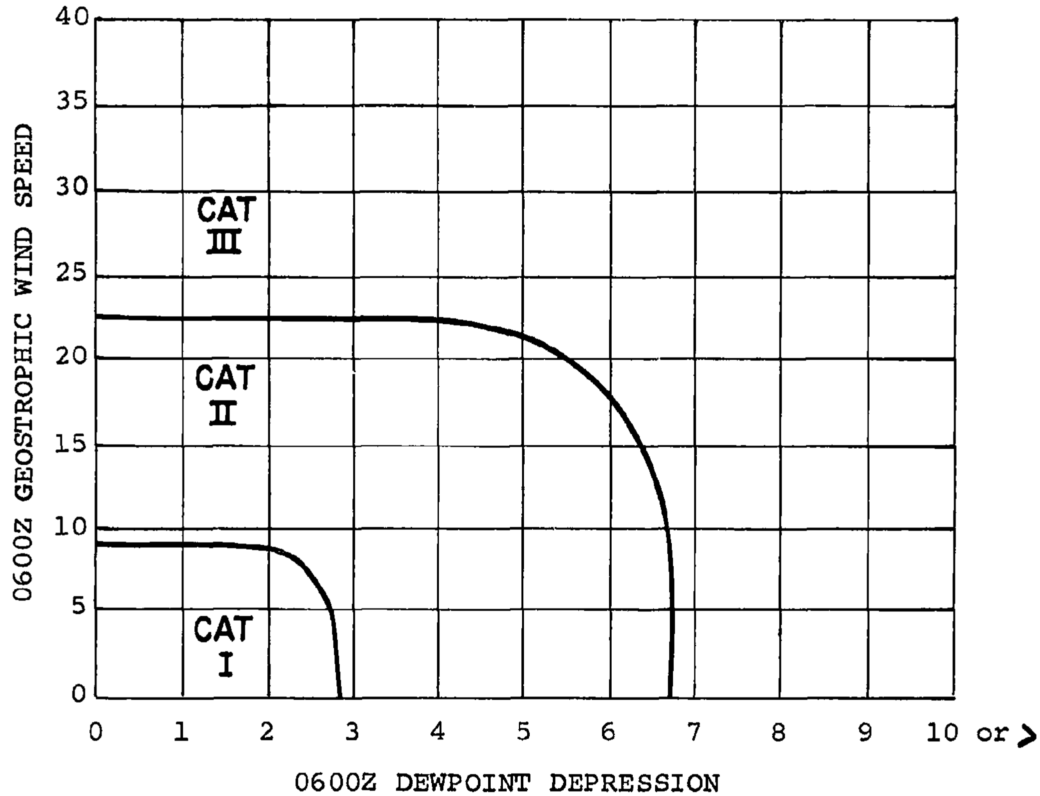


Fig. 18. For use in the months of October and November when the 0600Z visibility is less than 6 miles. With the 0600Z dewpoint depression and the 0600Z geostrophic wind speed, enter the graph and read directly the category for the forecast visibility at 1200Z.

IDLEWILD, PRE-TROUGH MARITIME, STAGE I

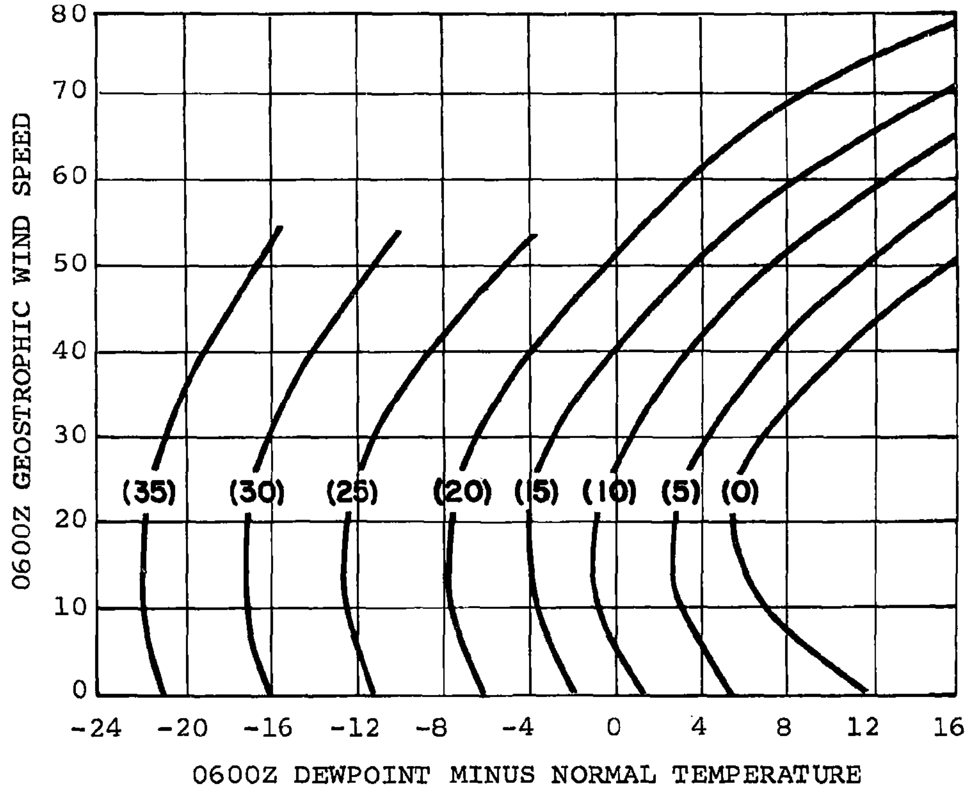


Fig. 19. For use in the months of December, January, February and March. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 20).

IDLEWILD, PRE-TROUGH MARITIME, STAGE II

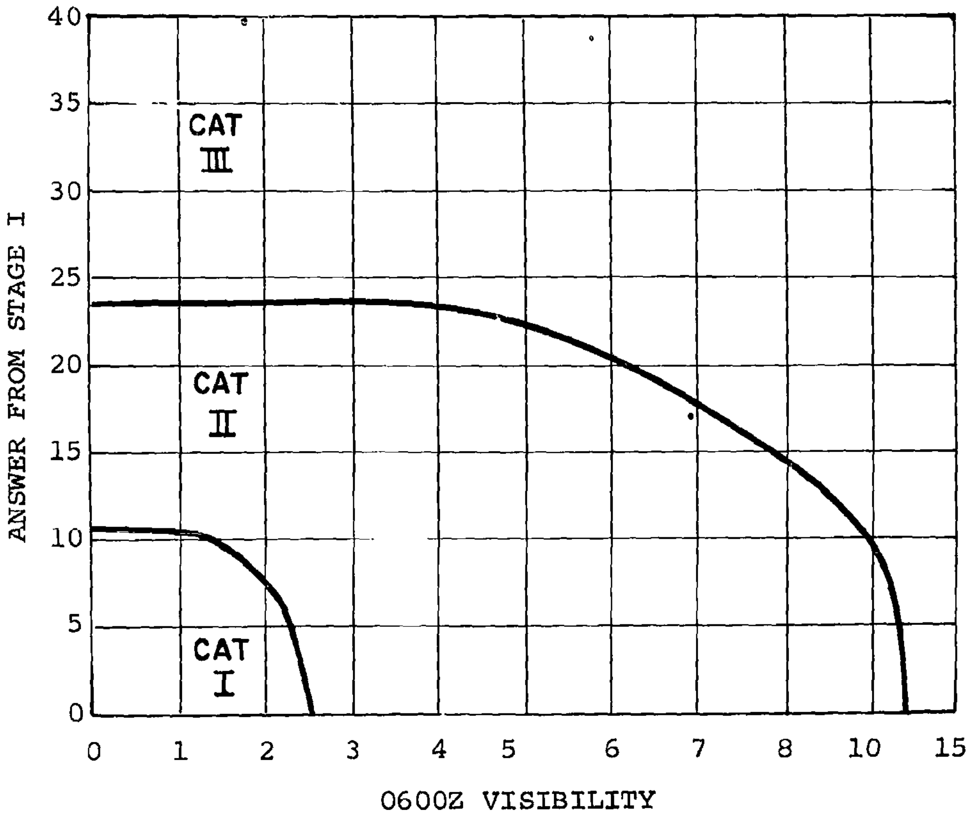


Fig. 20. For use in the months of December, January, February and March. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

IDLEWILD, PRE-TROUGH MARITIME, STAGE I

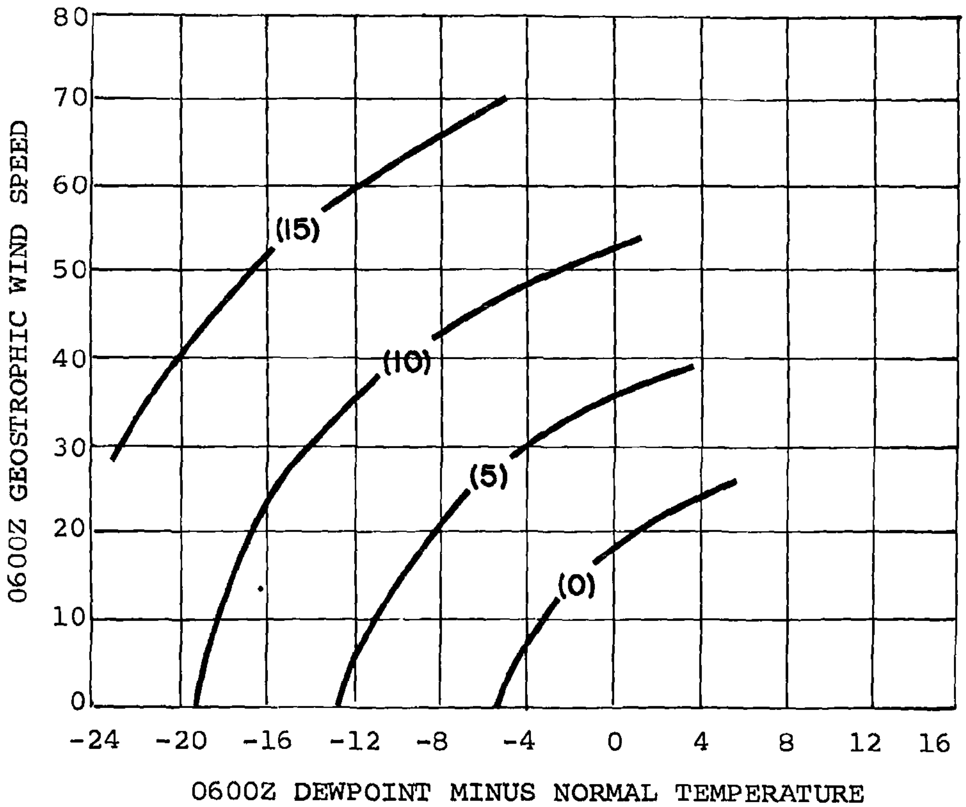


Fig. 21. For use in the months of April and May. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 22).

IDLEWILD, PRE-TROUGH MARITIME, STAGE II

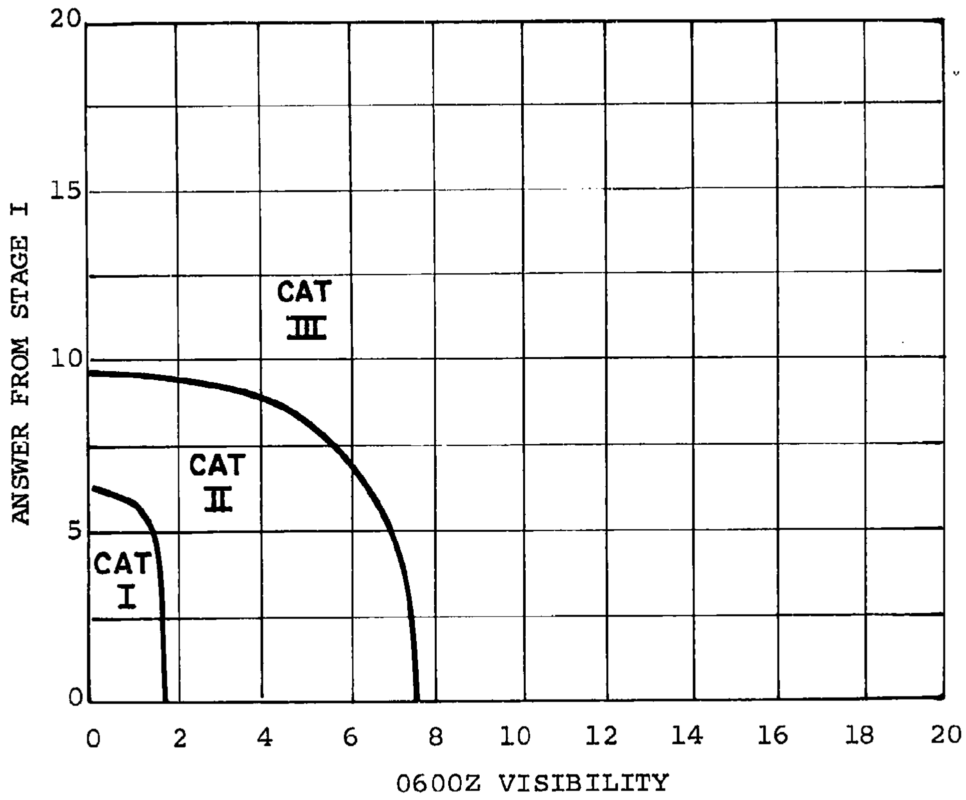


Fig. 22. For use in the months of April and May. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

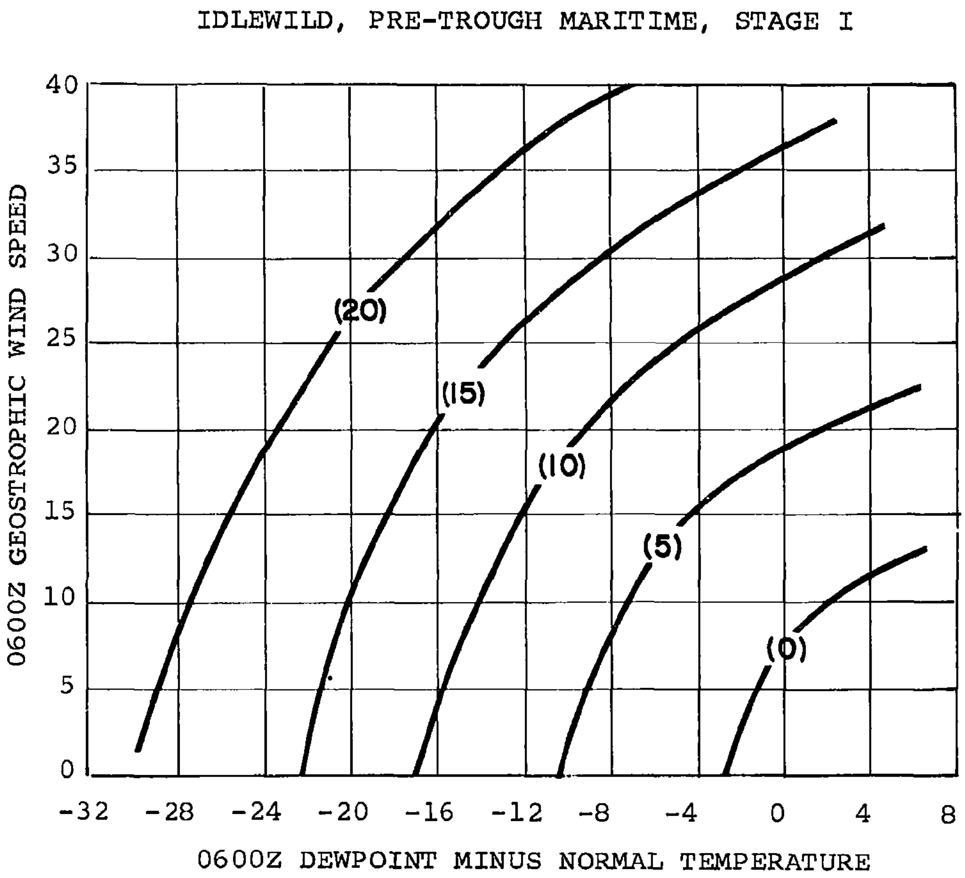


Fig. 23. For use in the months of June, July and August. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 24).

IDLEWILD, PRE-TROUGH MARITIME, STAGE II

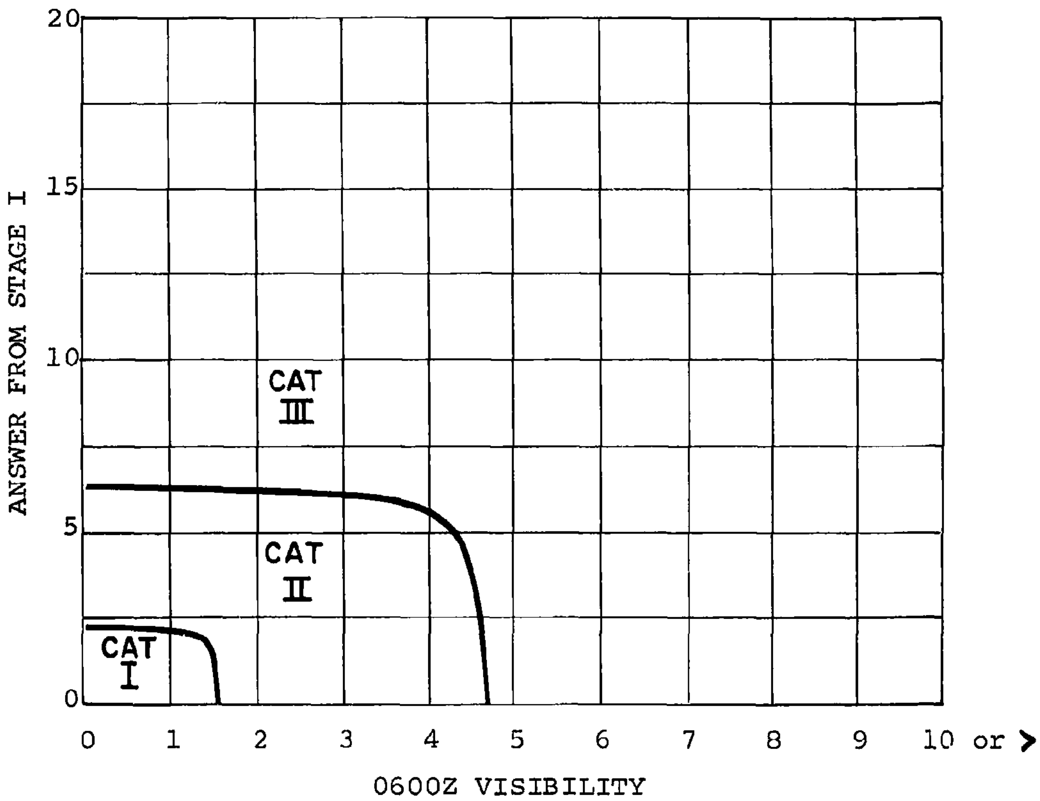


Fig. 24. For use in the months of June, July, and August. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

IDLEWILD, PRE-TROUGH MARITIME, STAGE I

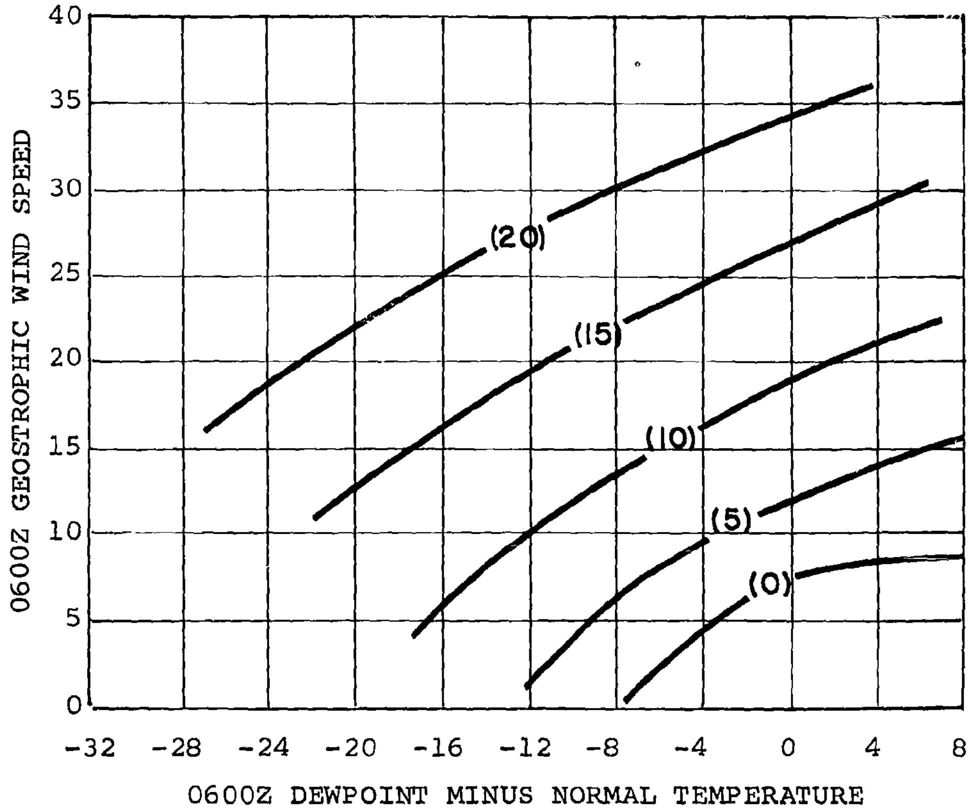


Fig. 25. For use in the month of September. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 26).

IDLEWILD, PRE-TROUGH MARITIME, STAGE II

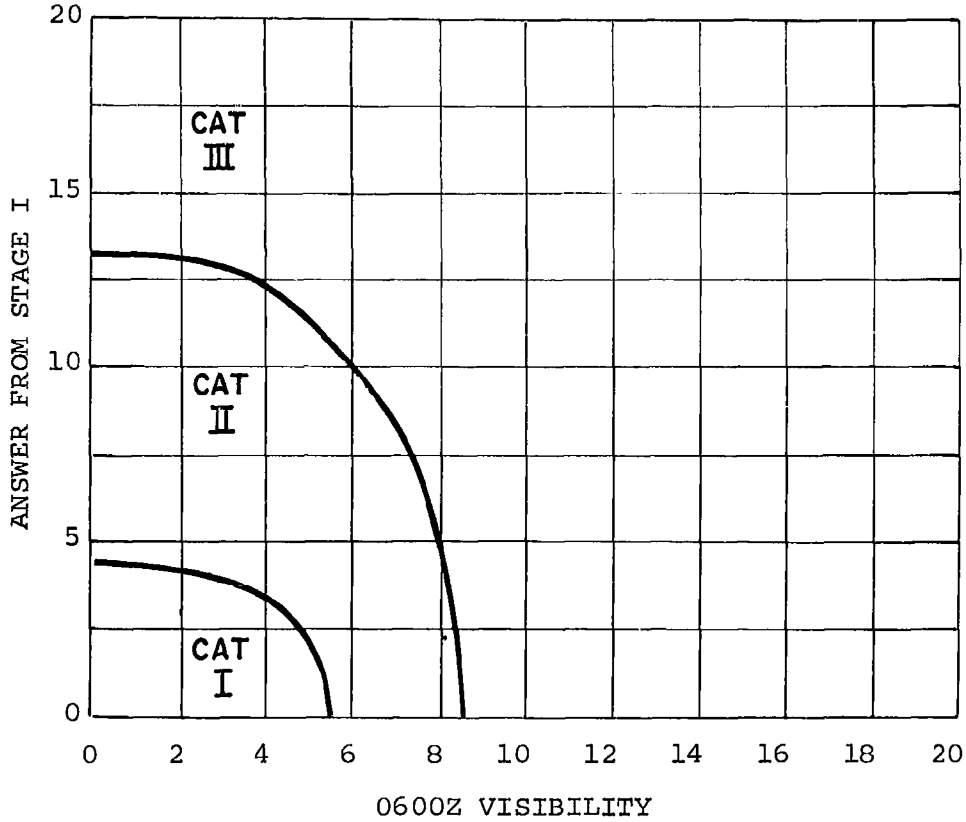


Fig. 26. For use in the month of September. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

IDLEWILD, PRE-TROUGH MARITIME, STAGE I

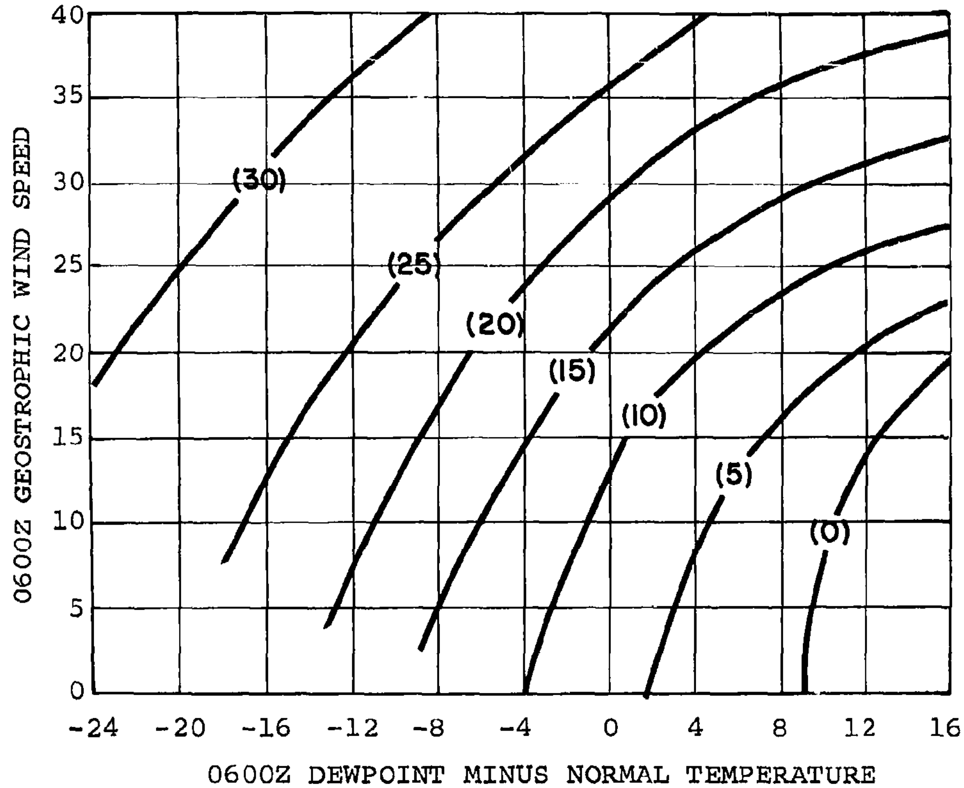


Fig. 27. For use in the months of October and November. With the 0600Z dewpoint minus the normal temperature (for the proper month) and the 0600Z geostrophic wind speed, enter the graph and read the weight value assigned to the point. This value is carried to Stage II (fig. 28).

IDLEWILD, PRE-TROUGH MARITIME, STAGE II

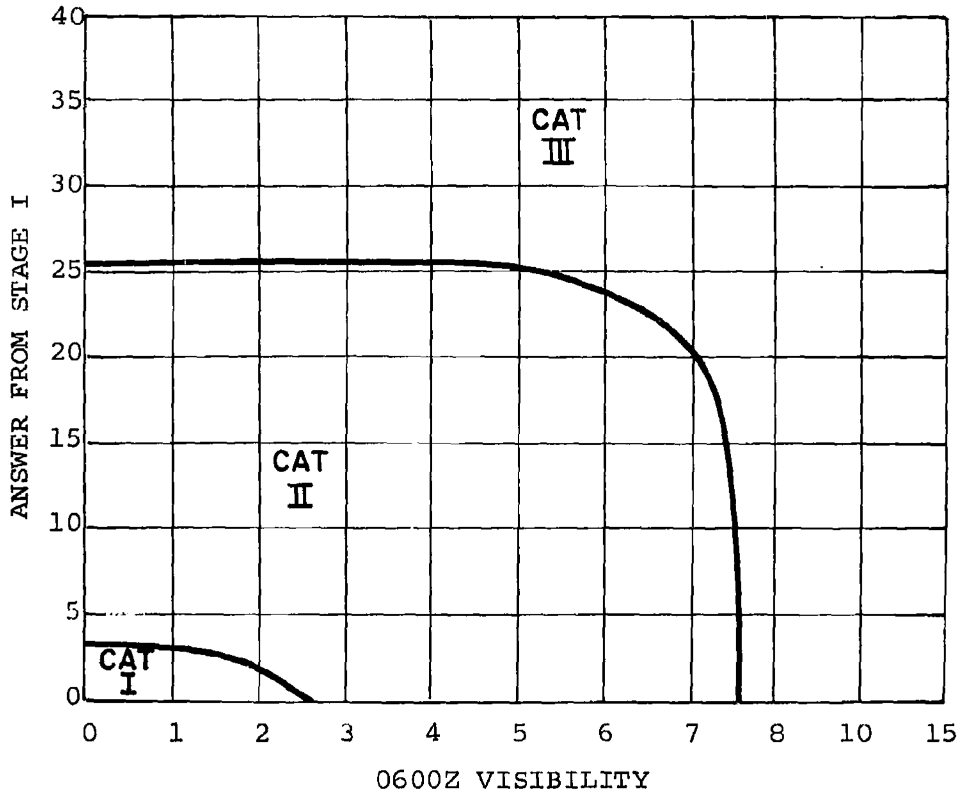


Fig. 28. For use in the months of October and November. With the answer from Stage I and the 0600Z visibility, enter the graph and read directly the category for the forecast visibility at 1200Z.

PRE-WARM FRONT

Introduction

The solutions presented have been developed only for Idlewild International Airport and have not been tested on Washington. The multiple solution presented in earlier reports has been abandoned due to its complexity for hand computation. A less cumbersome and streamlined computation has been substituted and two solutions presented. The first has been termed the "Seasonal Solution" since the data were grouped roughly according to three seasons: first, winter (December through March); second, spring (April through June); and lastly, summer-fall (July through November). The second solution presented is a "General" solution which groups all months as one but which varies the weight of the predictors on a monthly basis.

Considerable use is made of contingency tables (Panofsky and Brier, 5). The procedure is as follows: first, contingency tables were constructed for each of six predictors and the predictand, (the predictand being in terms of visibility categories as given earlier). Each predictor was separated into two or more intervals according to the manner in which it defined the predictand categories. Corresponding to each contingency table, a "no-relation" table was constructed. This was done by multiplying the column and row totals and dividing by the total cases. This expresses the number of cases which would appear in each box of the contingency table by chance.

Comparison of boxes of the two tables gives a clue as to the usefulness of the predictor. It is computed objectively by forming the ratio of a value from the contingency table to the value in the corresponding box of the "no-relation" table. When the ratio is at or near unity, the relationship is about equal to chance. When it is greater than one the relationship is better than chance; the usefulness being roughly proportional to the magnitude greater than unity.

Contingency Ratio Tables will not be given except when they are a part of the final solution. As an example, however, Tables II and III illustrate two such tables. Whenever a box in the contingency table contained no cases a minimum value of one-tenth (0.1) was used in place of zero as the contingency ratio.

TABLE II

0600Z VISIBILITY	CAT I	CAT II	CAT III
0-2 Miles	3.8	.7	.3
>2-4 "	1.5	1.9	.3
>4-6 "	.6	1.5	.8
>6 "	.1	.5	1.5

TABLE III

0600Z CEILING	CAT I	CAT II	CAT III
0-500 Feet	2.7	1.6	.1
600-900 "	2.0	.9	.8
1000-4000 "	.8	1.3	.9
4100-8000 "	.4	1.3	1.8
>8000, High Clouds & Clear	.4	.5	1.5

Both the Seasonal and the General solution make use of these general concepts but vary in particular application which will be explained in the individual sections.

Certain terms and observations at Idlewild are used in both solutions:

1. Dewpoint Depression. The 0600Z temperature-dewpoint difference (F°).
2. Ceiling. The 0600Z ceiling height in feet.
3. Visibility. The 0600Z visibility in miles with fractional units in halves, quarters, eighths or sixteenths.
4. Change in Visibility. The change of visibility as above subtracting the 0000Z value from the 0600Z value algebraically.
5. 850 mb Temperature. The 0000Z value of 850 mb temperature in C°.
6. 850 mb Height. The 0000Z value of 850 mb height in feet.

7. Surface Wind. The 0600Z surface wind in knots to 16 points of the compass.
8. Geostrophic Wind. The wind as determined objectively from the 0600Z pressure observations as explained in the Introduction using knots and a 36 point compass.
9. Water Temperature. The latest available sea temperature in F^{o} for Ambrose Light Ship.

Both solutions utilize a table of minimum values. That is, certain of the elements or observations appear to have a minimum value below which (above which in the case of dewpoint depression), Category I or Category II visibilities do not occur. These values are listed in Table IV. The column headings: Category I and II refer to the forecast visibilities. For instance, if a prediction of Category I visibility is made, the forecast is tested for minimum value, Category I, for each of the predictors listed under the appropriate month. If the particular element is less than the minimum shown, (maximum in the case of dewpoint depression), the forecast category should be increased one category. All cases of Category I which are tested and reduced to Category II should then be tested for Category II minimal values. It is not necessary to test cases which are forecast as Category III.

Seasonal Solution

The Contingency Ratio Values are combined in the seasonal solution. For economy of time pairs of predictors were combined. This was done by multiplying the contingency ratio values of each category to form all possible combinations of the predictors. Table V-A illustrates such a table. For example, under Category I in Table II the 0-2 miles contingency ratio is 3.8, the 0-500 foot value in Table III is 2.7, multiplied together the product is 10.2, Table V-A. Similarly, a visibility of $>$2 to 4 miles has a value of 1.5 and the ceiling bracket 600-900 feet a value of 2.0, their combined product is 3.0 and appears in Table V-A.

Each of the three seasonal solutions uses the same predictor pairs: (1) 0600Z Ceiling and 0600Z Visibility; (2) 0600Z Surface Wind and Visibility Change 0000Z to 0600Z; (3) 0600Z Dewpoint Depression and 850 mb Temperature. Geostrophic wind, is used as a final predictor and the contingency ratios are given as Tables V-D, VI-D, and VII-D.

TABLE IV

CUT-OFFS (ALL YEAR)

	CATEGORY I			CATEGORY II		
	Dec.-March	April-June	July-November	Dec.-March	April-June	July-November
0600Z Dewpoint Depression	$>5^\circ$	$>2^\circ$	None (July-Aug) $>1^\circ$ (Sept-Nov)	$>6^\circ$	$>7^\circ$	$>8^\circ$ (July-Aug) $>4^\circ$ (Sept-Nov)
0600Z Average Temperature-Dewpoint	$<32^\circ$	$<47^\circ$ Apr. $<50^\circ$ May-June	None (July-Aug) $<53^\circ$ (Sept-Nov)	$<24^\circ$	$<42^\circ$ Apr. $<46^\circ$ May-June	$<64^\circ$ (July-Aug) None (Sept-Nov)
Change Average Temperature-Dewpoint 0000-0600Z	$<-3^\circ$	None	None (July-Aug) $<-3^\circ$ (Sept-Nov)	$<-4^\circ$	None	$<-3^\circ$ (July-Aug) $<-7.5^\circ$ (Sep-Nov)
Change Visibility 0000-0600Z	None	None	None (July-Aug) $>+3\frac{1}{2}$ (Sept) >0 (Oct-Nov)	None	None	None
0600Z Temperature Minus Sea Temperature	$<-7^\circ$	$<-3^\circ$	None	$<-15^\circ$	$<-4^\circ$	$<-4^\circ$ (July-Aug) $<-6^\circ$ (Sept-Oct) None (Nov)
850 mb Temperature	$<-2^\circ$	$<9^\circ$	None (July-Aug) 9° (Sept-Nov)	$<-6^\circ$	$<6^\circ$	$<11^\circ$ (July-Sep) $<9^\circ$ (Oct) None (Nov)
850 mb Height	<464	<470	<484 (Sept-Nov) None (July-Aug)	<446	<461	<481 (July-Aug) <468 (Sept-Nov)
0600Z Ceiling	None	>600 Ft.	None (July-Aug) 1,100-16,000 (Sept-Nov)	None	None	None

The procedure then, is as follows:

1. Determine the values of the seven predictors.
2. Enter the appropriate values in Table V, VI, or VII, depending on the season. From each of the three individual tables in the particular season, extract a Category I, II, and III value from the three pairs of predictors.
3. Compute the sum of each of the three separate categories.
4. Multiply each of the sums by the corresponding contingency ratio value given for the geostrophic wind in that season.
5. Enter the seasonal graphs with the products of the Category I and II values just computed and note the forecast.
6. The winter solution contains an area of mixed categories and is referred to as a "twilight area." Any cases falling in this area are carried to fig. 30, which requires entry of Category II and III values for solution.
7. Check each Category I or II forecast for minimum values, Table IV, before determining final solution. Any cases which violate the minimum values should be forecast one category higher than the graphs indicate.

As an example, the case of March 5, 1955, 0600Z, will be tested. The following elements were observed or computed.

		Observation	
0600Z Ceiling	.....	500 feet	
0600Z Visibility	.....	4 miles	
0000Z Visibility	.....	15 miles	
0600Z Surface Wind	.....	North 14 knots	
0600Z Temperature	.....	30°F	Average 29°F
0600Z Dewpoint	.....	28°F	
0000Z Temperature	.....	33°F	Average 31°F
0000Z Dewpoint	.....	29°F	
0300Z 850 mb Temperature		7°C	
0300Z 850 mb Height	....	4850 feet	
0600Z Geostrophic Wind		120° 29 knots	
Sea Temperature	.....	39°	

The Contingency Ratio Values from Tables V-A, V-B, and V-C are:

TABLE	Contingency Ratio Value CAT I	CAT II	CAT III
V-A	4.1	3.0	.1
V-B	1.1	1.6	.7
V-C	1.8	1.4	.5
TOTAL	7.0	6.0	1.3

The geostrophic wind contingency ratio given in Table V-D for Categories I, II, and III are, respectively:

1.5 1.3 .7

The sums given above are multiplied by the corresponding geostrophic contingency ratios. The products are 10.5, 7.8, and 0.9. The first two values, 10.5 and 7.8 are entered on the ordinate and abscissa of fig. 29. The plot falls in the Category I area and is tested for minimum values in Table IV. It will be noted that the average temperature-dewpoint is 29°F and falls 3 degrees below the minimum allowed for Category I in Table III. It is then tested with Category II minimum values and meets all requirements, therefore a forecast of Category II is called for. The observed 1200Z visibility was 3 miles, Category II.

The technique is similar for all seasons. The only variation is the possibility of cases falling in the "twilight" area in winter, in which case the Category II and III values are needed. Category III contingency ratios are eliminated from Tables VI and VII since they are not used.

Winter (December through March)

Tables V-A, V-B, V-C, give the contingency ratio values for the six parameters. The values are added for each category value separately and multiplied by the corresponding value of geostrophic wind, Table V-D. Enter fig. 29 with the Category I product on the ordinate and the Category II value on the abscissa. The plot determines a forecast value unless it falls in the mixed are (twilight area). If this is the

TABLE V-A

	CATEGORY I				CATEGORY II				CATEGORY III			
0600Z CEILING												
0-500	10.2	4.1	1.6	.3	1.1	3.0	2.4	.8	.1	.1	.1	.2
600-900	7.6	3.0	1.2	.2	.6	1.7	1.4	.5	.2	.2	.6	1.2
1000-4000	3.0	1.2	.5	.1	.9	2.5	2.0	.7	.3	.3	.7	1.4
4100-8000	1.5	.6	.2	.1	.9	2.5	2.0	.7	.5	.5	1.4	2.7
>8000 & None	1.5	.6	.2	.1	.4	1.0	.8	.3	.5	.5	1.2	2.3
0600Z Visibility	0-2	>2-4	>4-6	>6	0-2	>2-4	>4-6	>6	0-2	>2-4	>4-6	>6

TABLE V-B

SURFACE WIND									
<5 All Directions	.1	3.7	4.4	.8	.8	1.4	.6	.4	.3
NE >4 Knots	.1	1.0	1.1	.9	.9	1.6	1.5	1.0	.7
ESE-SSW >4 Knots	.1	1.6	1.8	.7	.7	1.3	1.5	1.0	.7
SW-NNW >4 Knots	.1	.5	.5	.6	.6	1.1	2.0	1.3	.9
Visibility Change	>0	0 to -3	<-3	>0	0 to -3	<-3	>0	0 to -3	<-3

TABLE V-C

DEWPOINT DEPRESSION												
5	.1	.1	.1	.1	.1	.4	.4	.5	3.3	2.2	2.0	1.0
4-5	.1	.1	.3	.9	.1	1.3	1.2	1.6	1.7	1.2	1.1	.5
1-3	.1	.1	.5	1.8	.1	1.0	1.1	1.4	1.5	1.0	1.0	.5
0	.1	.1	1.8	6.3	.1	.9	.8	1.1	.8	.5	.5	.2
850 Temperature	<-7	-7/-4	-3/1	>+1	<-7	-7/-4	-3/1	>+1	<-7	-7/-4	-3/1	>+1

case, enter fig. 30 with the product of Category II values on the ordinate and Category III values on the abscissa and determine the forecast. Test all Category I and Category II solutions with the minimum values given for each category in Table IV. If the case does not meet all of the individual tests, forecast one category higher and test further if necessary. If all criteria are met, forecast as shown in figs. 29 or 30.

TABLE V-D

GEOSTROPHIC WIND		CAT I	CAT II	CAT III
10-110°	>10 knots	.1	.5	1.6
190-240°	>10 knots	.1	1.2	1.1
120-180°	(any speed)	1.5	1.3	.7
250-310°	(any speed)	Indeterminate (lack of cases)		
320-360°	(any speed)	3.8	.7	.4
10-110°	<11 knots	3.8	.7	.4
190-240°	<11 knots	3.8	.7	.4

Spring (April through June)

The contingency ratio values for the six predictors are given in Tables VI-A, VI-B, and VI-C. These tables are similar to the preceding section, except that since Category III values are not needed, they have been omitted.

TABLE VI-A

CEILING	CATEGORY I			CATEGORY II		
0-600 Feet	12.0	4.8	.2	.1	1.0	.8
700-7000 "	.5	.2	.1	.1	1.4	1.2
>7000 "	.2	.8	.1	.1	1.0	.8
0600Z Visibility (Miles)	0-1	>1-4	>4	0-1	>1-4	>4

TABLE VI-B

SURFACE WIND	CATEGORY I			CATEGORY II		
< 6 knots	1.8	3.5	1.2	.4	.4	.4
NE-SSW 6-10 kts	.6	1.1	.4	1.1	1.1	1.1
NW-NNE 6-10 kts	.1	.1	.1	1.9	1.9	1.9
All dir >10 kts	.1	.1	.1	1.0	1.0	1.0
Change in Visibility 0000Z to 0600Z (Miles)	<-2½	-2½ to +½	>+½	<-2½	-2½ to +½	>+½

Contingency ratio values for surface winds SSW to WNW, 6-10 knots, were indeterminate due to lack of dependent cases.

TABLE VI-C

850 MB TEMPERATURE	CATEGORY I				CATEGORY II			
< 8°	1.6	.6	.1	.1	.4	.4	.6	.1
8-11°	1.2	.5	.1	.1	1.2	1.2	1.7	.1
> 11°	7.8	3.3	.2	.2	.8	.8	1.2	.1
0600Z Dewpoint Depression	0	1-2	3-7	>7	0	1-2	3-7	>7

Each category value is added separately and multiplied by the corresponding contingency value of the geostrophic wind from Table VI-D.

TABLE VI-D

GEOSTROPHIC WIND		CATEGORY I	CATEGORY II
< 11 knots		2.3	.7
70-130°	>10 knots	.3	1.0
140-220°	>10 knots	1.0	1.2
230-60°	>10 knots	Indeterminate (lack of cases)	

Enter the ordinate of fig. 31 with the Category I product and the abscissa with the Category II product. The plot determines the preliminary forecast value. All Category I and II solutions must be tested for minimum values by use of Table IV. If the case does not meet all of the individual tests, forecast one category higher and test further if necessary. If all criteria are met forecast as shown in fig. 31.

Summer-Fall (July through November)

The contingency ratio values for the predictors are given in Tables VII-A, VII-B, and VII-C. Again only Category I and II values are needed and presented.

TABLE VII-A

0600Z CEILING	CATEGORY I			CATEGORY II		
0-1000 feet	.2	1.0	6.0	.4	1.1	1.9
>1000 "	.1	.1	1.2	.1	.9	1.5
0600Z Visibility (Miles)	>10	5-10	<5	>10	5-10	<5

TABLE VII-B

SURFACE WIND 0600Z	CATEGORY I			CATEGORY II		
<6 knots	1.0		3.0	1.0		2.4
NNE-ENE >5 knots	.5		1.5	.4		1.0
E-S >5 knots	.1		.2	.8		2.0
SSW-N >5 knots	.1		.2	.1		.1
Change in Visibility 0000-0600Z (Miles)	>-1/8		<0	>-1/8		<0

TABLE VII-C

850 MB TEMPERATURE	CATEGORY I			CATEGORY II		
$>14^{\circ}$	.1	.1	3.3	.5	1.7	2.7
$10-14^{\circ}$	.1	.1	4.6	.3	1.1	1.8
$<10^{\circ}$	.1	.1	.3	.1	.2	.3
0600Z Dewpoint Depression	>4	2-4	0-1	>4	2-4	0-1

Each category value is added separately and multiplied by the corresponding contingency value of the geostrophic wind from Table VII-D.

TABLE VII-D

GEOSTROPHIC WIND		CATEGORY I	CATEGORY II
< 11 knots		3.3	1.2
10-90°	> 10 knots	.1	.7
100-190°	> 10 "	.9	1.1
200-360°	> 10 "	.1	.1

Enter the ordinate of fig. 32 with the Category I product and the abscissa with the Category II product. This determines a preliminary forecast value. All Category I and II solutions must be tested for minimum values by use of Table IV. If the case does not meet all of the individual tests, forecast one category higher and test further if necessary. If all tests are satisfied, forecast as shown by the plot of fig. 32.

Seasonal Results

Skill scores were computed by standard methods against chance and persistence. The percentage correct is also given.

DEPENDENT CASES: WINTER

		Forecast I	Forecast II	Forecast III
Observed	I	16	2	0
Observed	II	0	27	6
Observed	III	0	6	51

Skill score-Random forecasts = .79
Skill score on Persistence = .658
Percent right = 87%

SPRING

		Forecast	
	I	II	III
Observed I	9	0	1
II	1	19	0
III	0	6	13

Skill score-Random forecasts = .74
Skill score on Persistence = .64
Percent right = 83.7%

SUMMER-FALL

		Forecast	
	I	II	III
Observed I	6	0	0
II	1	18	4
III	0	3	32

Skill score-Random forecasts = .78
Skill score on Persistence = .68
Percent right = 87.6%

A small sample of data (52 cases), was reserved for independent test and the results are given below.

			Forecast	
		CAT I	CAT II	CAT III
Observed	CAT I	3	3	0
	CAT II	1	13	3
	CAT III	1	2	26

Percent correct: 80.7%

General Solution

In addition to the Seasonal technique, a General method was developed, which is applicable any month. It includes the same predictors and in addition makes use of two new ones and a variation on the 850 mb temperature. It is necessary when devising a method to bridge seasonal changes to develop predictors which exhibit seasonal changes without changing value as the year progresses. For example, the difference between the Idlewild dewpoint and the ocean temperature is used as an active parameter. Both values have large seasonal changes but the differences remain within the same general limits. Similarly, the 850 mb temperature is subtracted from a value which changes regularly with time.

The contingency ratio method is used to weight predictors. In the general method predictors are paired graphically and then separated into areas suggested by the data. The cases in each area are then analyzed by the contingency ratio method. Values from the four pairs of predictors are added and plotted on a graph against the geostrophic wind direction, (actually one of two graphs, depending on the geostrophic wind speed). Certain areas of this graph contained mixed Category II and III cases and was called a "twilight" zone. Cases in this area are subject to further test by three additional graphs similar to the initial set, but emphasizing Category II cases. Areas on these graphs are weighted by the contingency ratio technique and the sums of the three graphs are plotted against the geostrophic wind direction to arrive at a solution.

The list of minimum values, Table IV, is again used to test each prediction of Category I and Category II visibility.

The following additional definitions apply:

1. <u>Change in dewpoint</u>. The change in dewpoint between 0000Z and 0600Z; plus for increasing values and minus for decreasing.

2. <u>Difference dewpoint-sea temperature</u>. The 0600Z dewpoint minus the latest available sea temperature from Ambrose Light Ship.

3. <u>850 mb temperature departure</u>. The value of the 0000Z 850 mb temperature minus the temperature for the day listed in Table VIII below.

The values given in Table VIII were determined by plotting 850 mb temperatures for all Category I cases in the dependent sample against day of the year. A smoothed line representing the minimum observed of these cases was drawn and values for every 10 days interpolated and put in tabular form.

TABLE VIII

Month/Day	1	10	20	30
January	$-2^{\circ}C$	$-2^{\circ}C$	$-3^{\circ}C$	$-3^{\circ}C$
February	-3	-3	-2	-2 (28th)
March	-2	-1	-1	0
April	0	1	2	4
May	4	5	7	9
June	9	11	13	15
July	-	-	-	-
August	-	-	-	-
September	15	14	12	11
October	11	10	9	7
November	7	6	5	4
December	4	2	0	-2

July and August 850 mb temperatures were indeterminate due to lack of Category I cases. In these two months consider the difference of the 0000Z 850 mb temperature minus the 850 mb temperature departure to be zero.

Method

The predictors are paired and combined graphically in figs. 33, 34, 35 and 36. The box in the upper left-hand corner gives the contingency ratio value for each of the lettered areas in main body of the graph. The geostrophic wind speeds have been grouped into winds greater than 10 knots and winds 10 knots and less, this criterion alone determines whether fig. 37 or 38 is used.

The procedure is as follows:

1. Determine the value of the nine predictors.

2. Enter the values as called for in figs. 33, 34, 35, and 36. Note the area determined by the plot of the particular predictor pair on each graph.

3. Compute the sum of the contingency ratios for figs. 33, 34, 35, and 36.

4. If the grostrophic wind speed is greater than 10 knots, enter fig. 37, (if less than 11 knots enter fig. 38), with the sum of the contingency ratio values on the ordinate and the geostrophic wind direction on the abscissa. Note the forecast. (If the case falls in the "twilight" area proceed to 6, below).

5. Check each Category I and II forecast for minimum values, Table IV, before determining the final solution. Any cases which violate the minimum values should be forecast one category higher than the graphs indicate.

6. Cases which fall in the "twilight" area of fig. 37 require further test. The predictors are paired graphically on figs. 39, 40 and 41. Note the area determined by the plot of the particular predictor pair on each graph and then note the contingency ratio value for that area on each graph.

7. Compute the sum of the contingency ratio values for figs 39, 40 and 41.

8. Enter these sums on the ordinate of fig. 42 and the geostrophic wind direction on the abscissa. Note the forecast.

9. Category II forecasts must be tested for minimum values in Table IV before determining the final solution. Any cases which violate the Category II values are forecast as Category III.

The case of March 5, 1955 is used as an example. This is the same example used in the previous method. The following additional predictors are computed.

1. Change in dewpoint 0000-0600Z: $-1^{\circ}F$
2. Dewpoint minus sea temperature: $-11^{\circ}F$
3. 850 mb temperature departure: $+9^{\circ}C$

The contingency ratio values from figs. 33, 34, 35 and 36 are:

Figure 33	Area B	1.3
Figure 34	Area A	4.4
Figure 35	Area D	0.4
Figure 36	Area B	1.2
	TOTAL	7.3

The geostrophic wind is greater than 10 knots so 7.3 is entered on the ordinate of fig. 37 and the geostrophic direction of 120° is entered on the abscissa. This plot falls in the area of Category I visibility. As described in the previous section, the case does not meet Category I requirements for average temperature-dewpoint and is forecast correctly as Category II.

General Results

Skill scores against chance and persistence are given.

		FORECAST		
		CAT I	CAT II	CAT III
	I	27	4	2
OBSERVED	II	5	57	12
	III	0	12	101

Skill score - random = .73
Skill score - persistence = .71
Percent correct = .84

A small sample of data was saved for independent test and the results are given below.

		FORECAST		
		CAT I	CAT II	CAT III
	I	4	1	0
OBSERVED	II	2	12	3
	111	1	3	25

Percent correct: .80

The summer errors appeared to outweigh errors in other proportional seasons. Perhaps a lot of this is due to the earlier hour of sunrise which is not accounted for but which certainly adds to the complexity of the problem.

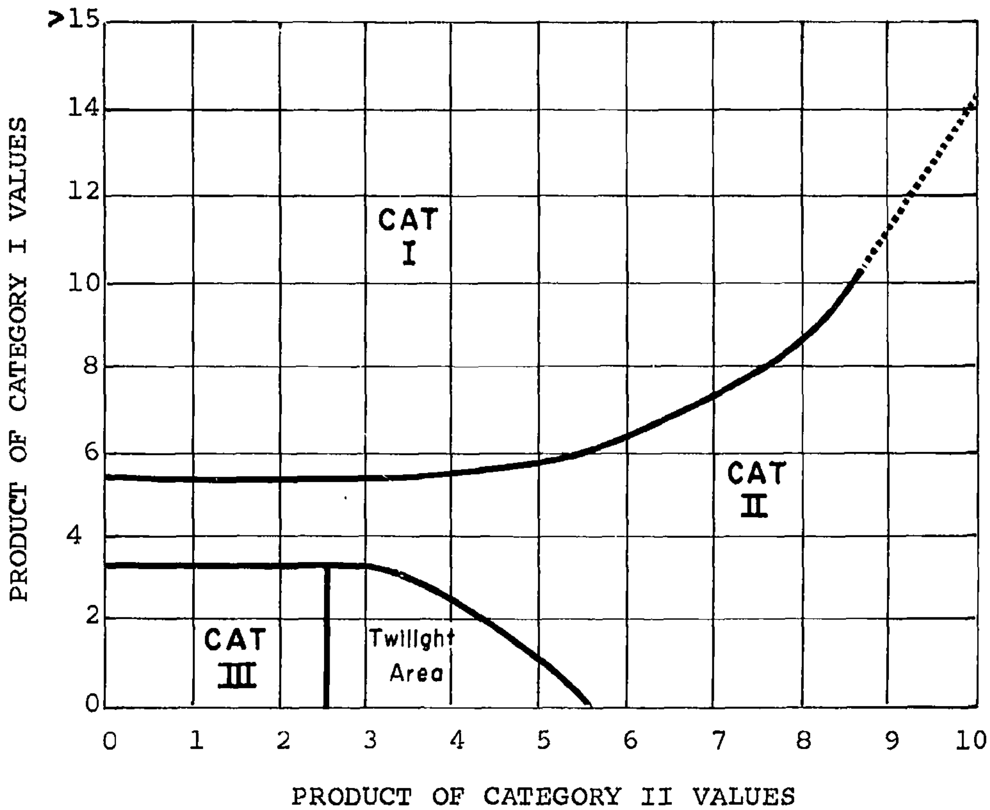


Fig. 29. For use in the months of December, January, February and March. With the product of Category I and Category II values, enter the graph and note the forecast. Any cases falling in the "twilight area" are carried to fig. 30 for a solution. Cases in the other areas are checked for minimum values before determining a final solution; see text, and Table IV.

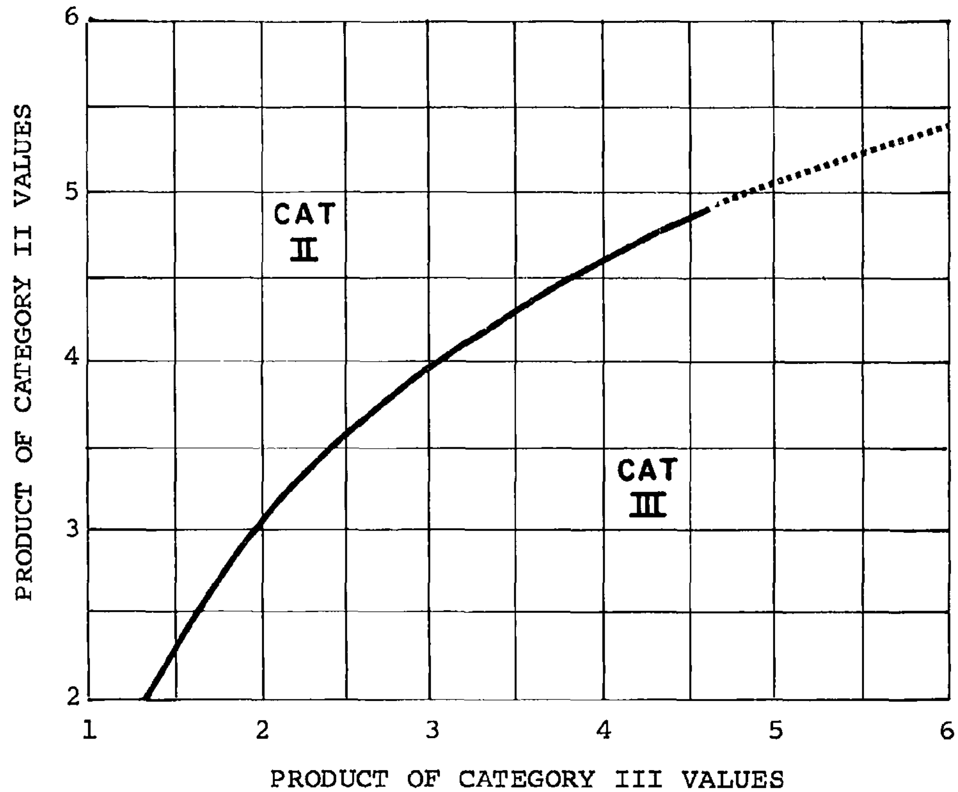


Fig. 30. For use in the months of December, January, February and March. With the product of Category II and Category III values, enter the graph and note the forecast. The Category II forecast is checked for minimum values before determining a final solution, see text and Table IV.

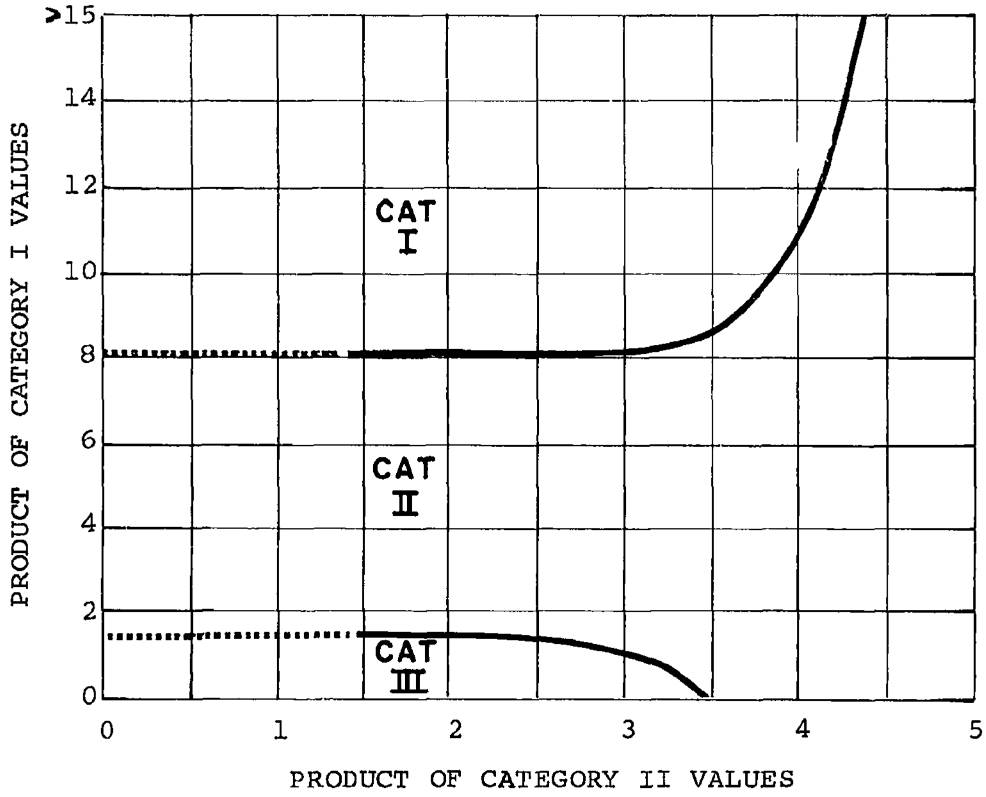


Fig. 31. For use in the months of April, May and June. With the product of Category I values and Category II values, enter the graph and note the forecast. The forecast falling in the Category I or II area is checked for minimum values before determining a final solution. See text and Table IV.

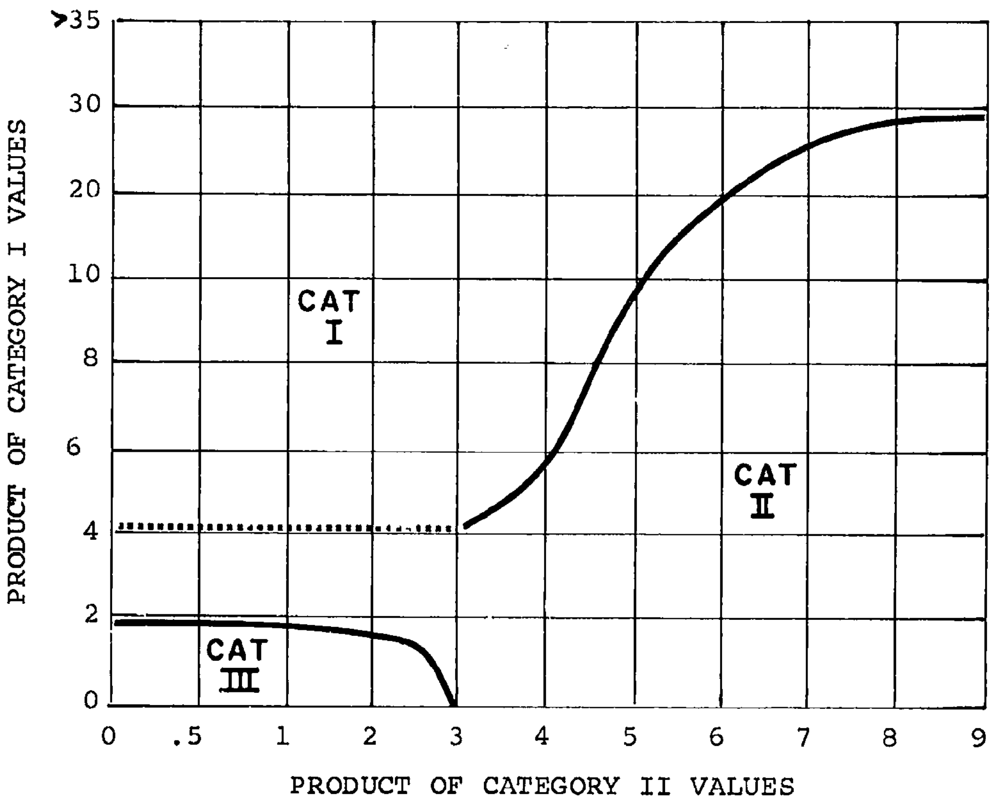


Fig. 32. For use in the months of July, August, September, October and November. With the product of Category I values and Category II values, enter the graph and note the forecast. Forecasts falling in the Category I or II area are checked for minimum values before determining a final solution. See text and Table IV.

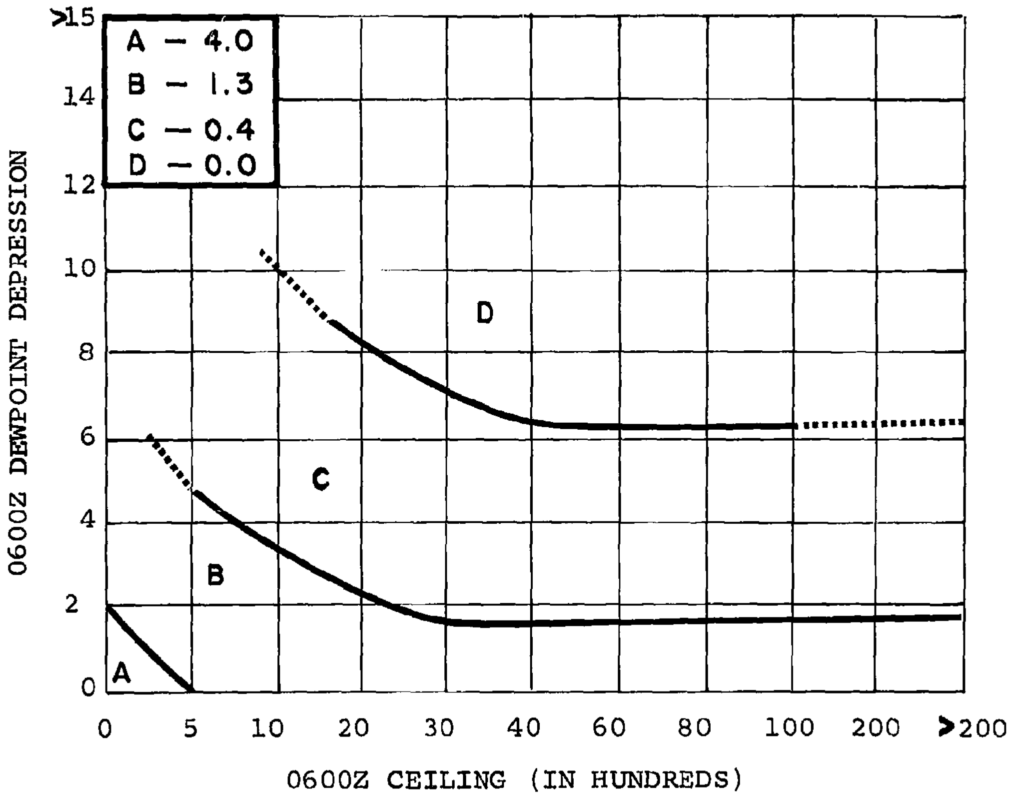


Fig. 33. Visibility Forecast, Stage 1. For use in any month of the year. Enter the 0600Z ceiling (in hundreds of feet) on the abscissa and the 0600Z dew-point depression along the ordinate. Record the value determined by this plot with respect to areas.

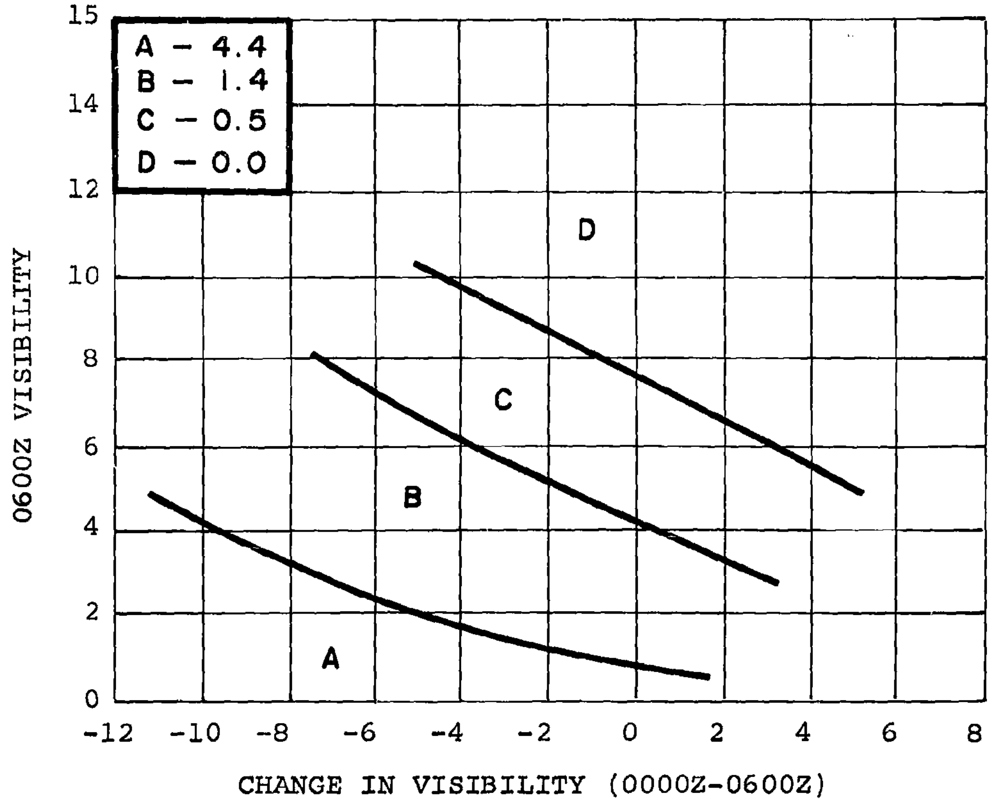


Fig. 34. Visibility Forecast, Stage 2. For use in any month of the year. Enter the change in visibility from 0000Z to 0600Z on the abscissa and the 0600Z visibility along the ordinate. Record the value determined by this plot with respect to areas.

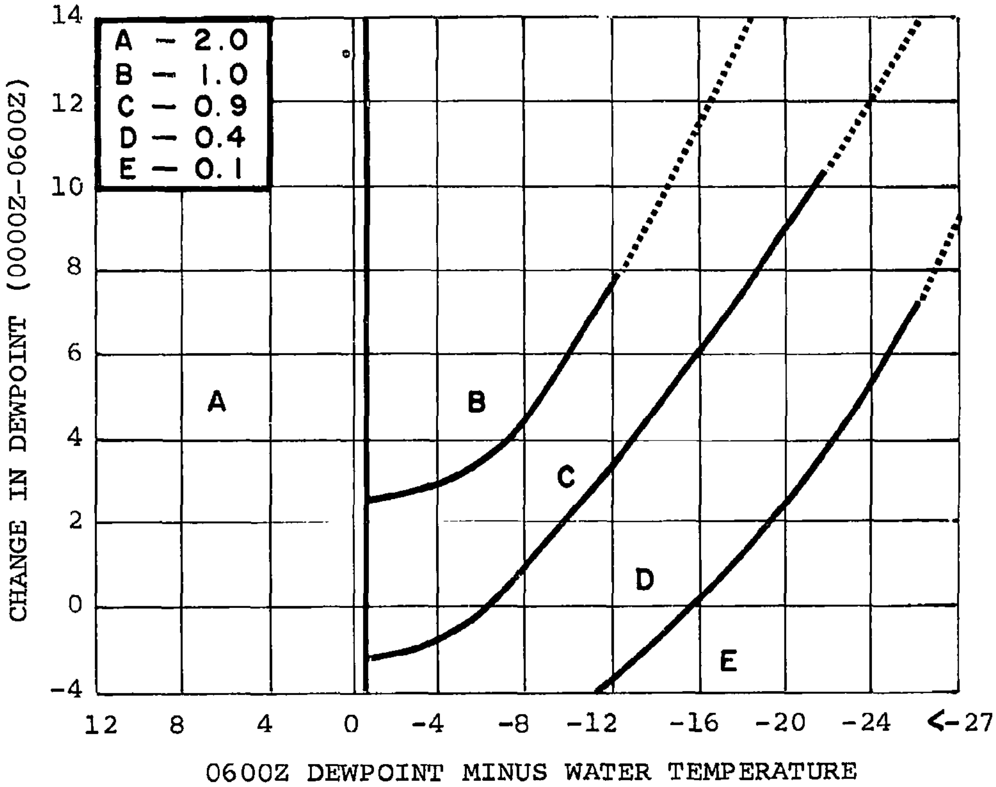


Fig. 35. Visibility Forecast, Stage 3. For use in any month of the year. Enter the 0600Z dewpoint minus the water temperature on the abscissa and the change in dewpoint from 0000Z to 0600Z along the ordinate. Record the value determined by this plot with respect to areas.

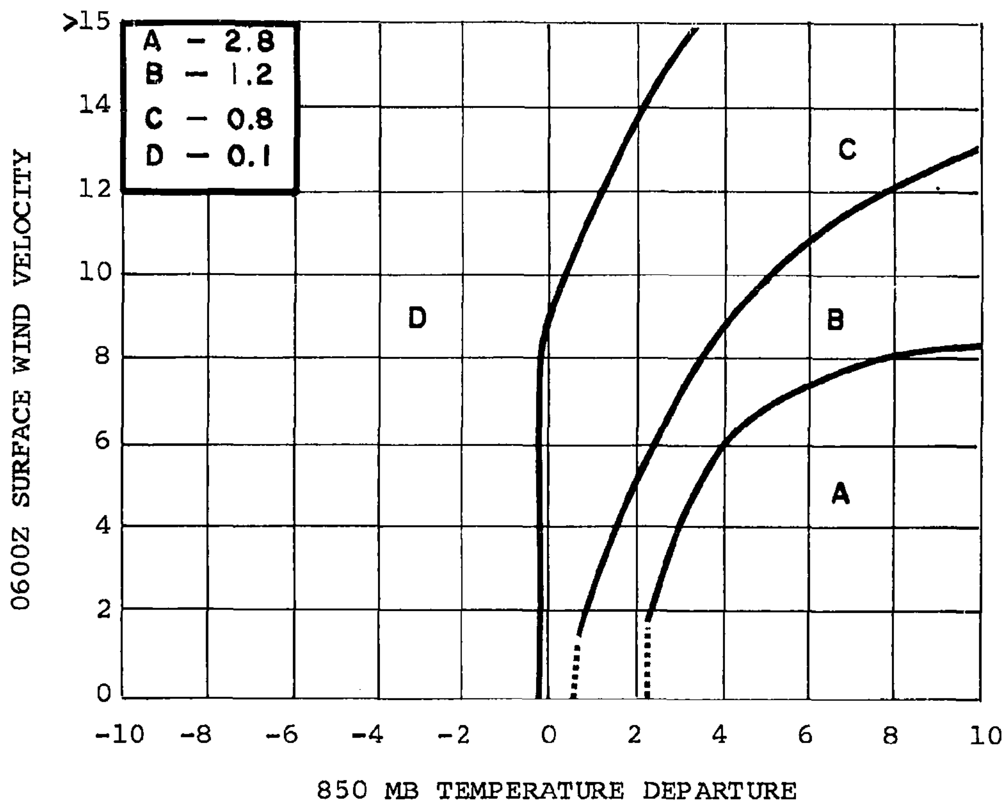


Fig. 36. Visibility Forecast, Stage 4. For use in any month of the year. Enter the 850 mb temperature departure (Table VIII) on the abscissa and the 0600Z surface wind velocity along the ordinate. Record the value determined by this plot with respect to areas.

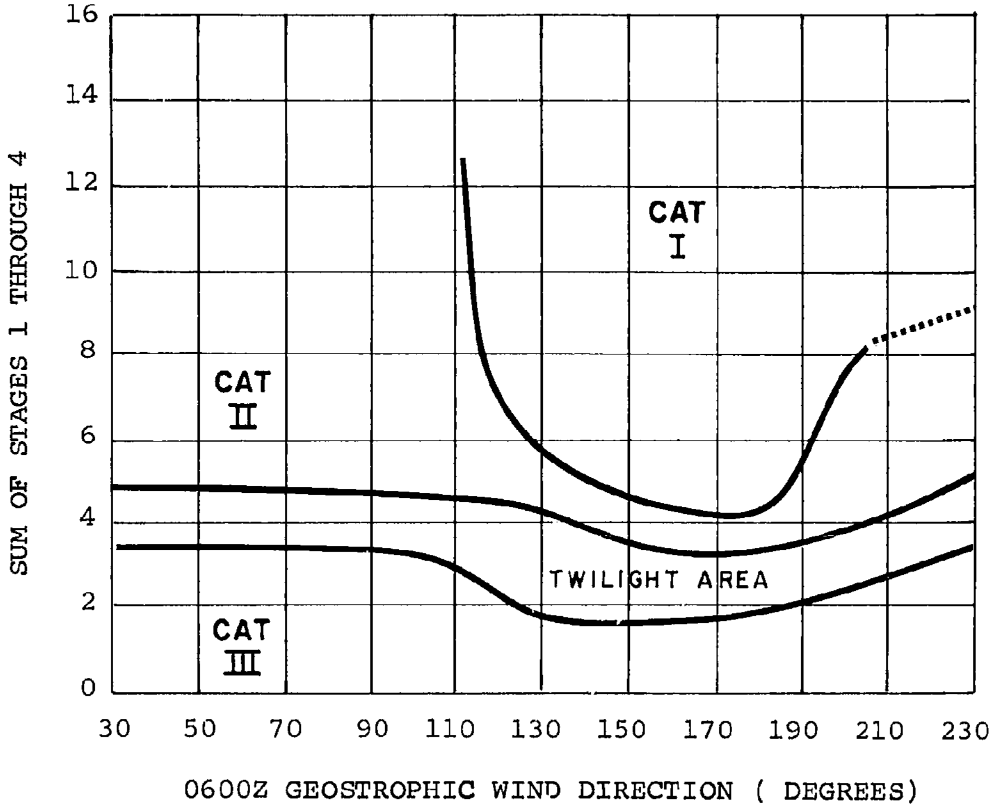


Fig. 37. Visibility forecast, Final Stage (Geostrophic Wind Speed Greater Than 10 Knots). For use in any month of the year. Enter the 0600Z geostrophic wind direction on the abscissa and the sum of the values recorded from Stages 1 through 4 along the ordinate. Any case falling in the "twilight area" requires further examination. (See figs. 39 through 41.) Cases in the CAT I or II areas are checked for minimum values before determining a final solution, Table IV.

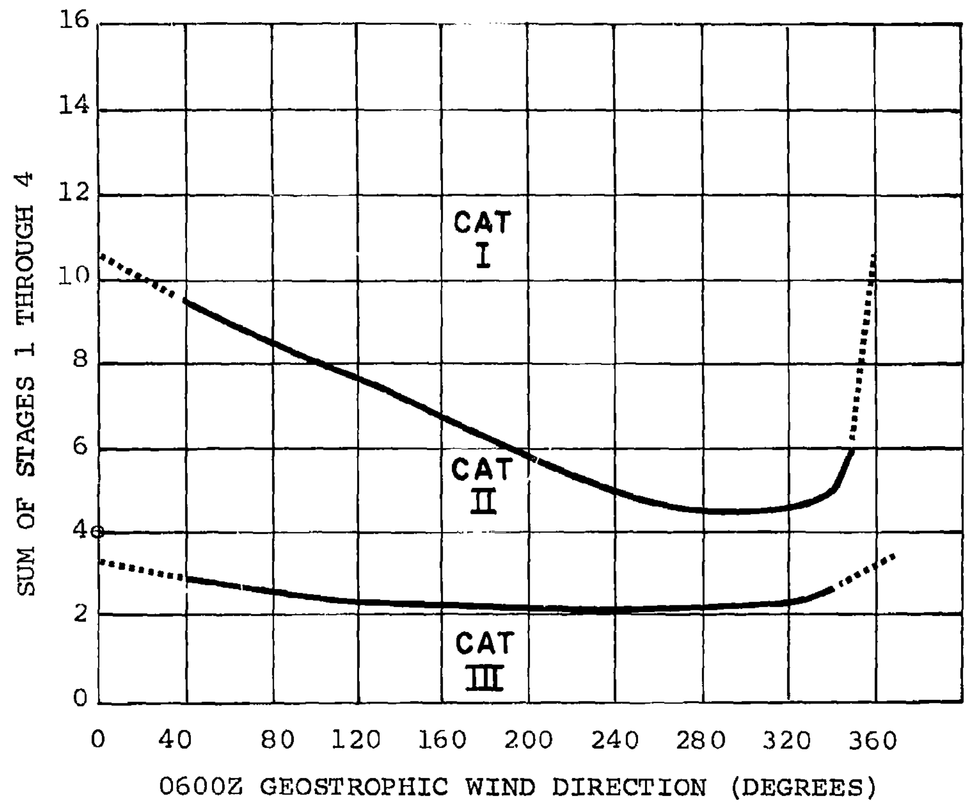


Fig. 38. Visibility Forecast, Final Stage, (Geostrophic Wind Less than 11 Knots). For use in any month of the year. Enter the 0600Z geostrophic wind direction on the abscissa and the sum of the values recorded from stages 1 through 4 along the ordinate. Cases falling in the Category I or II area are checked for minimum values before determining a final solution, Table IV.

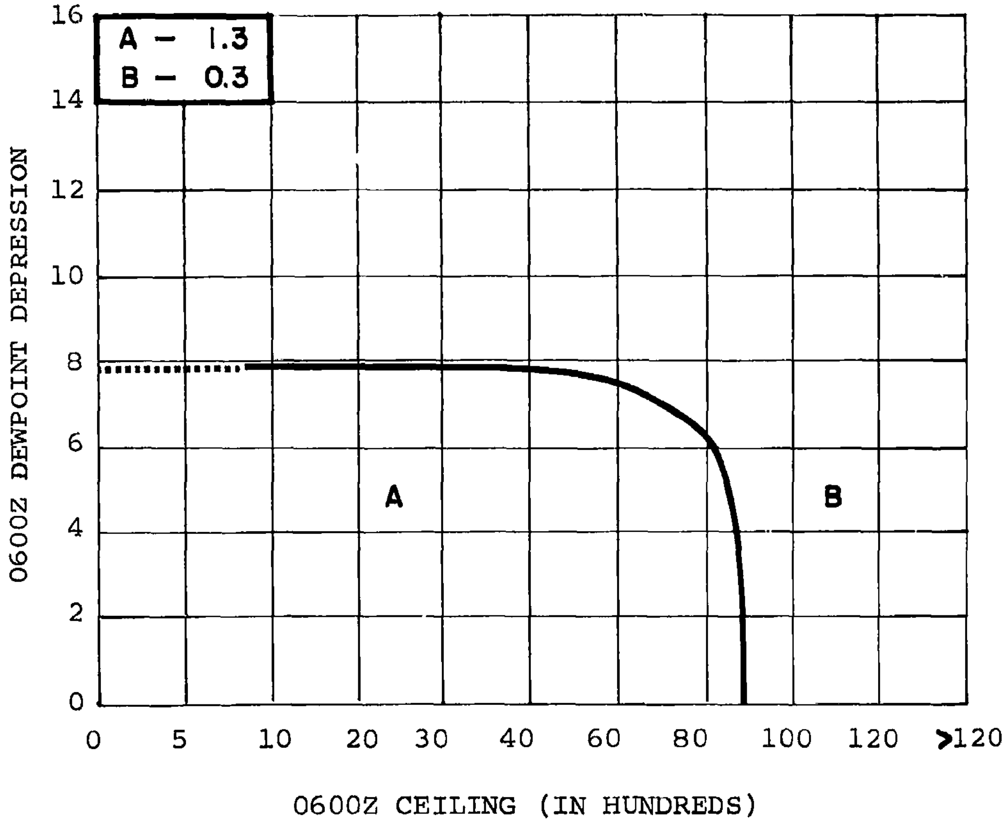


Fig. 39. Visibility Forecast, Twilight Area, Stage 1. For use in any month of the year. Enter the 0600Z ceiling (in hundreds of feet) on the abscissa and the 0600Z dewpoint depression along the ordinate. Record the value determined by this plot with respect to areas.

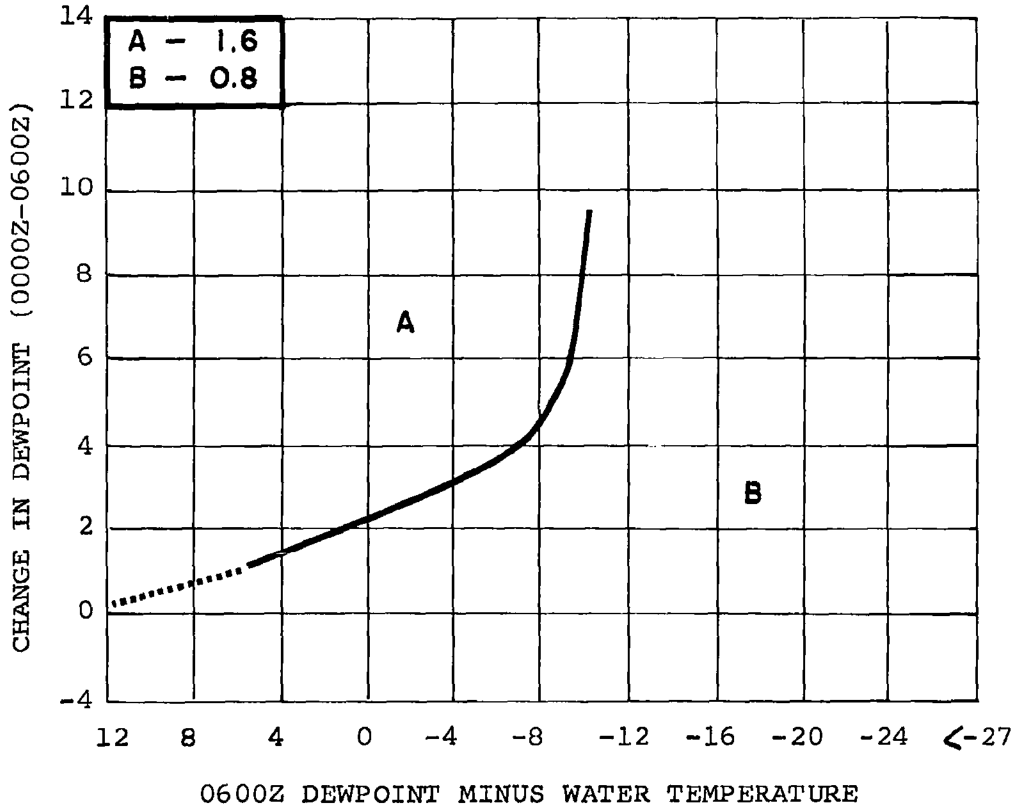


Fig. 40. Visibility Forecast, Twilight Area, Stage 2. For use in any month of the year. Enter the 0600Z dewpoint minus the water temperature on the abscissa and the change in dewpoint from 0000Z to 0600Z along the ordinate. Record the value determined by this plot with respect to areas.

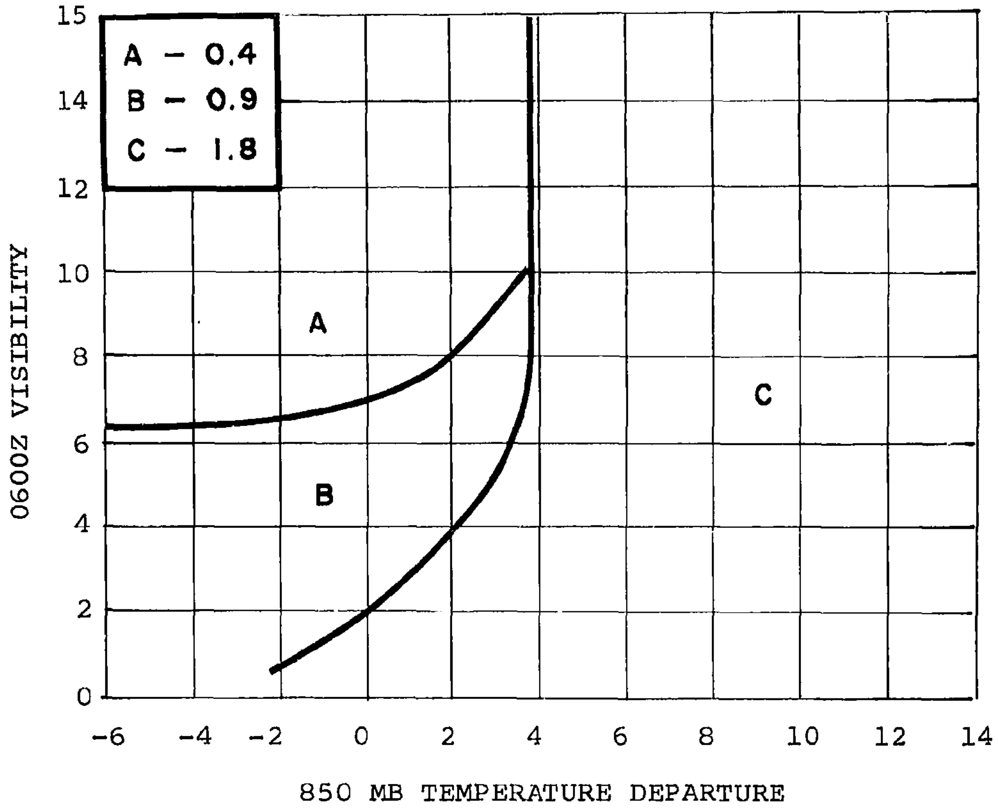


Fig. 41. Visibility Forecast, Twilight Area, Stage 3. For use in any month of the year. Enter the 850 mb temperature departure (Table VIII) on the abscissa and the 0600Z visibility along the ordinate. Record the value determined by the plot with respect to areas.

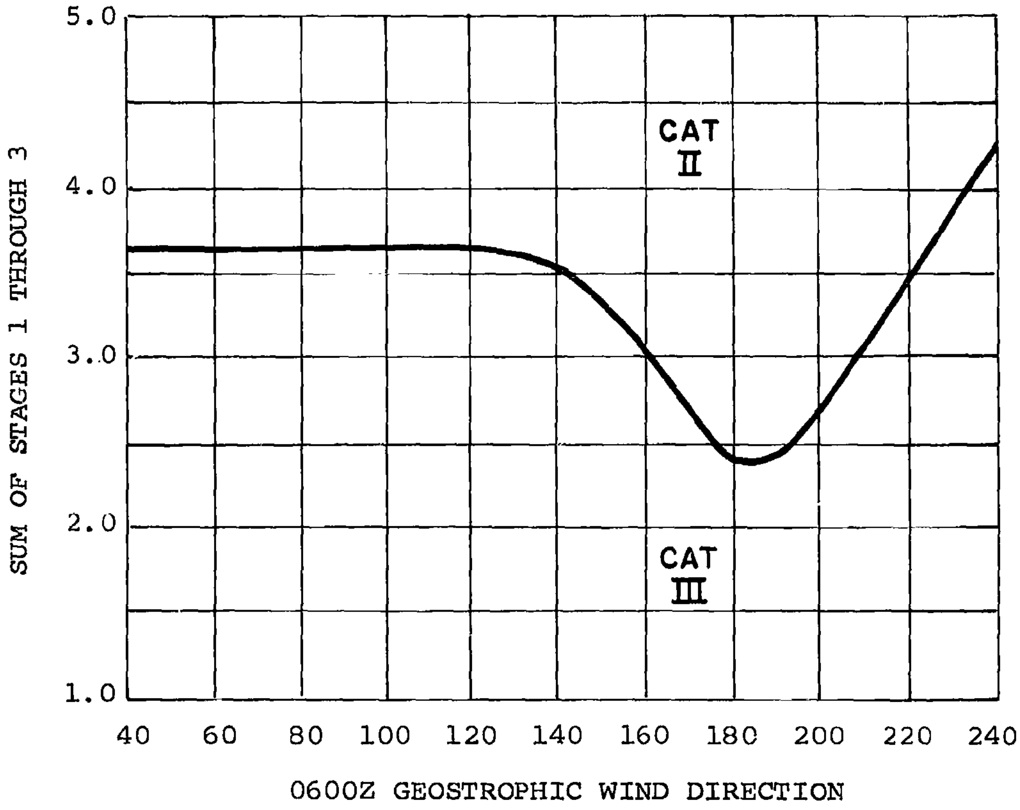


Fig. 42. Visibility Forecast, Twilight Area, Final Stage. For use in any month of the year. Enter the 0600Z geostrophic wind direction on the abscissa and the sum of Stages1 through 3 along the ordinate. Cases falling in the Category.II area are checked for minimum values before determining a final solution, Table IV.

SUMMARY AND ANALYSIS

The primary purpose of this research was to develop objective short-range forecasting techniques which could start from any time base and be applicable in any geographic location. The particular assignment was the investigation of visibility forecasting methods. These methods were to be adaptable to rapid calculation (especially EDP) in the 433L program and were to be based on synoptic models.

The pressure patterns which have been described in the report are recognized in most forecasting offices. Objective definition of the patterns may not be easy and while this is part of the problem, it was felt that such definition would best be handled later if the techniques derived from the subjective patterns were found to be useful. Very few days presented much discussion as to the type of pattern, however, strict objective classification has not been achieved.

No attempt was made to vary the time of forecast beginning. The most difficult six-hour time period, midnight to dawn, was chosen deliberately in the hope that solutions for a universal starting period would derive from that by a set of modifying predictors. However, lack of research time precluded this part of the investigation.

The geographic solution by choosing a landlocked station, Washington, and a seaboard station, Idlewild, was attempted. The solutions include basic predictors which attempt to recognize the stability and moisture content of the air mass and, as such, it appears that the solutions as presented will have applicability at other locations. It is anticipated, however, that local influences must modify the basic solution when the location is shifted, and this statement will probably be true in many cases, regardless of predictors chosen. For example, terrain and smoke pollution effects must be taken into account.

The solution for pre-trough synoptic patterns is basically the same at Idlewild as it is at Washington, however it was necessary to add a modifying predictor to take local smoke into account. Similarly, the effect of a body of water in some quadrant will have an effect on the low level stability depending on whether it is warmer or colder than the maritime model chosen. Post-low or post-cold front cases will show much poorer results at a station like Cleveland, Ohio than at Washington. In the former case, considerable shower activity due to the proximity of Lake Erie will cause a larger percentage of Category II visibilities than at Washington which has strong downslope influence under post-cold front conditions.

It is estimated that decision-tree models could be constructed by experienced personnel well acquainted with local effects, but that only broad ranges of internal predictor values could be assigned without use of a dependent sample.

Advection predictors were investigated and it was found that, due to the short forecast time period involved, time-change predictors were about as effective and had complete objectivity. Space and time advection predictors were difficult to make objective, especially in the eastern quadrants of Idlewild where ocean data are sparse. For that reason 6-hour changes in dewpoint, temperature and visibility were used in place of more complex advection parameters. It would be expected that advection predictors would be a requirement for forecast periods of 12 hours and longer.

During the course of the contract approximately 14 man days were spent in consultation with the System Integration Contractor. During these discussions it was decided that solutions would not be bound by simple decision-tree methods but that tabular and scatter-diagram techniques would be acceptable as long as objectivity was preserved. In the methods described, once the synoptic pattern has been classified, the predictors are objective and can be determined from teletype data alone. While some of the computations may appear complex when the report is viewed as a whole, it will be found that any particular solution is relatively fast and the computation limited to addition and multiplication.

It is quite difficult to put many of the "line forecasters" methods into objective terms. No complex or subjective predictors were used such as might be used by the forecaster. The solutions do present in an orderly fashion the basic questions that enter every visibility forecast:

1. Is this the type of situation which causes visibility problems?

2. Is the air mass stable and moist?

Solutions with good results follow this orderly investigation. Possibly higher accuracy could be achieved if more "elegant" predictors were included, however, in many cases experience has shown that such parameters cause as many missed forecasts as they hit. Certainly air mass history and accelerations of all predictors are a part of the solution and further study should include an investigation of their part of the forecast.

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4. Geophysics Research Directorate, Forecasting Relationships Between Upper Level Flow and Surface Meteorological Processes. Geophysical Research Papers No. 23, 18 (1953).

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